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NAVEDTRA 12970
January 1992
0502-LP-213-6700

Naval Education and
Training Command

Training Manual
(TRAMAN)

Principles of Naval Ordnance and Gunnery

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Naval Education And Training Program Management Support Activity

PRINCIPLES OF NAVAL ORDNANCE AND GUNNERY

NAVEDTRA 12970

DEPARTMENT OF THE NAVY
CHIEF OF NAVAL EDUC AND TNG

1992 Edition Prepared by
GMC(SW) L. S. Harris

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PREFACE

This training manual (TRAMAN), Principle of Naval Ordnance and Gunnery, NAVEDTRA 12970, and the nonresident training course (NRTC), NAVEDTRA 82970, form a self-study package that will acquaint officer candidates, junior officers, and senior enlisted personnel with the many facets of the ordnance world. It will also serve as a helpful general reference for ordnance personnel. Primary emphasis is placed on presenting a complete but general description of the combat system equipment found on modern U.S. Navy surface vessels. Additional coverage of other areas is included but limited to the description of the various types of explosive ordnance exclusive of their detection, control, and delivery systems.

Taken in sequence, the text guides the student through the ordnance world from the basic terminology of ordnance to the interface of sophisticated combat system equipment. Coverage of the material is as complete as possible without going into the technical aspects of how each piece of equipment functions.

This TRAMAN and NRTC were prepared by the Naval Education and Training Program Management Support Activity, Pensacola, Florida, for the Chief of Naval Education and Training.

1992 Edition

Stock Ordering No.
0502-LP-213-6700

Published by
NAVAL EDUCATION AND TRAINING PROGRAM MANAGEMENT
SUPPORT ACTIVITY

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON, D.C.:1992

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations as we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CHAPTER 1

INTRODUCTION TO NAVAL WEAPONS SEAPOWER AND YOU

The seapower of the United States includes all vessels and aircraft used to protect and control the sealanes vital to national interest. We must keep these sealanes open for the free use of ourselves and our allies. At the same time we must deny their use by our enemies in time of war.

The employment of our nation's seapower in support of this mission depends both upon the weapons systems available aboard ships and aircraft and their effective use by our naval leaders. As a leader at sea, you must know the capabilities and limitations of your weapon systems. In battle, you will be called upon to push yourself, your personnel, and your equipment to the limit. You are the seapower arm of national policy, and only through training and study will you meet the task. We have designed this text to give you a general sense of the weapon systems in the fleet today. Do not consider it as a substitute for in-depth study or training on any particular system.

WEAPONS TERMINOLOGY

Throughout this text you will encounter many unfamiliar terms. Most are defined in Appendix I. Since each chapter is a building block for later chapters, we will begin with some definitions of the basic words used in the weapons world.

ORDNANCE AND BALLISTICS

ORDNANCE is the term covering all weapons, weapons system components, and support equipment (guns, ammunition, missiles, launchers, bombs, rockets, mines, torpedo fire control, etc.).

BALLISTICS is the science of projectile motion. This includes all types of projectiles and their flight characteristics from firing to target impact. Specialists carefully study these properties because they are central to solving the fire control problem.

WEAPON SYSTEM TERMS

WEAPON SYSTEM. A weapon system is defined as the combination of a weapon (or multiple weapons) and the equipment used to bring the destructive power of the weapon against the enemy.

- GUN. A gun is a tube, closed at one end, from which a projectile is ejected at high speed, by the gases produced from rapidly burning propellant.

- GUIDED MISSILE. A guided missile is a self-propelled projectile whose path can be changed in flight through its own internal mechanisms. A ballistic missile is one that is guided to a certain point, then allowed to fall (or go ballistic) on a predetermined trajectory to its target.

- ROCKET. A rocket is a self-propelled projectile, much like a guided missile, except that its path cannot be changed after it is fired.

- TORPEDO. A torpedo is a self-propelled underwater missile used against surface and subsurface targets.

- MINE. A mine is an underwater, nonpropelled, explosive device, exploded when approached or contacted by surface or subsurface targets.

- FIRE CONTROL SYSTEM. A fire control system consists of the electronic and mechanical equipment used to track targets, compute the projectile to target intercept point, and generate delivery unit control orders (gun mount, missile launcher, etc.). A typical antiair or antisurface fire control system consists of a director, radar, stable element, and computer.

Directors, normally mounted high on the superstructure, incorporate radar (optical range finders on some older systems) for tracking and determining the targets bearing, range, and elevation. Missile directors with their radars are also used to guide the missile during certain phases of flight.

Computers take data from the director, radar, and other sources; they analyze it, and generate a fire control solution that aims gun mounts and missile launchers and guide missiles.

Stable elements are gyroscopes used primarily with gun fire control systems to provide a stable horizontal reference.

Radar uses echoes of high frequency radio pulses to provide continuous values for range, bearing, and elevation to the computer. These values correspond to the line-of-sight to the target.

- DETECTION SYSTEMS. A detection system consists of a radar or sonar that is used to detect, track, and determine the threat of a target.

- LAUNCHER. Launchers are positioning devices used to fire missiles or rockets. They position the missile and provide circuits to the missile for initial guidance and firing from the fire control system.

- GUN MOUNT. A gun mount consists of all the machinery used to position, load, and fire a gun.

- GUN TURRET. The description of a gun turret is the same as for a gun mount. A turret's loading system, however, rotates with the turret in train, from top to bottom; a gun mount's loading system is stationary below the gun house.

IDENTIFICATION OF ORDNANCE EQUIPMENT

Never underestimate the importance of cataloging, classification, and standardized nomenclature when dealing with ordnance. In fact, the word **ordnance** is related to the word **order**, in the sense of arrangement or classification. Its use in connection with weapons dates back to the time of England's Henry VIII, who had the royal armament classified and cataloged.

Ordnance cataloging, classification, and standard nomenclature, which were a welcome innovation in the 16th century, became an unavoidable necessity in the 20th. We do not consider it feasible or necessary to describe the many complexities involved in the classification and cataloging of weapons in this text. We will, however, explain enough for you to understand and recognize common weapon system nomenclatures.

NOMENCLATURE AND IDENTIFICATION

The standard nomenclature of any item of naval ordnance equipment includes a basic noun, sometimes descriptive adjectives, and identifying numbers. Let's look at 5"/54 caliber Mk 42 Mod 10 dual-purpose, rapid fire, single gun mount. Reading from left to right, **5 inch** specifies the bore diameter, **54 caliber** specifies the length of the barrel in calibers (one caliber equals one inch). In this case, the 5"/54 gun has a barrel length of 5 × 54 = 270 inches. The **Mk 42 Mod 10** indicates the particular design version. **Dual-purpose** indicates that the gun is designed for use against both air and surface targets. **Rapid fire** indicates that the gun is automatically loaded, **single** means that the gun has a single barrel. The basic noun here is **mount**, which includes not only the gun barrel but also the loading system, train and elevation, and all other equipment that is physically part of the gun.

So far we have discussed the identification of an entire system. Note, however, that every system is composed of many subassemblies—each having its own nomenclature (including mark and modification numbers and serial number). This identification system is used on most ordnance with the exception of radars, sonars, and fire control radars.

These systems use a slightly different form; for example, AN/SQS-23 sonar. The **AN** means that the nomenclature complies with the system adopted jointly by the armed forces. In the next group **SQS**, the first **S** identifies the type of installation (in this example, it stands for **water surface craft**.) The **Q** stands for the type of equipment (in this case, **sonar and underwater sound**,) and the last **S** indicates the purpose of the equipment (in this case, **detecting and/or range bearing**). The **23** serves as a model number (much like the mark number mentioned earlier).

Navy ordnance equipment procured from the Army normally retain the Army model numbers. An example is the M1911A1 .45-cal pistol, the **M** corresponds to the Navy's **Mark** for model, and the **A** to the Navy's **Mod** for modification. The number **A1** indicates the first modification.

NAME PLATES AND OTHER EQUIPMENT IDENTIFICATION

Each item of equipment assigned a mark and mod number (or its equivalent) bears a metal name plate secured to its exterior in plain view. The plate will contain the following data:

Standard nomenclature

Standard Navy stock number

Name of procuring naval agency (primarily NAVSEA)

Manufacturer's part or drawing number

Name of manufacturer

Contract number the equipment was procured under

Serial number and other identifying numbers

In addition to this information, the plate will also have blank spaces for recording equipment alteration numbers (called ORDALTS).

The preceding paragraphs cover only the bare necessities of equipment identification and nomenclature systems in the Navy. They are very broad and complex systems whose importance becomes more evident when you consider the interface with the Navy Supply System. This means being able to order repair parts, an essential function if you are to maintain your equipment.

ORGANIZATIONAL RESPONSIBILITIES

Any military organization must make some provision for the procurement of weapons, for supplying them with ammunition and personnel, installing them on vessels, and keeping them working and up to date.

In the United States military system, from the Navy's point of view, these responsibilities are assigned most importantly at three levels. These three levels are the Department of Defense (for the entire military), the Department of the Navy, and the individual ships weapons department along with NAVSEA. (These responsibilities appear also at other organizational levels, but we will not discuss them in this text.)

THE DEPARTMENT OF DEFENSE

The Department of Defense (see organizational chart, fig. 1-1) is administered by the Secretary of Defense, who is the principle assistant to the President in all matters relating to the department. He is a civilian appointed by the President to the President's cabinet, with the advice and consent of the Senate. His primary assistant in the area of weapons development, procurement, and testing is the Assistant Secretary of Defense for Production and Logistics, who reports to him through the Under Secretary of Defense for Procurement.

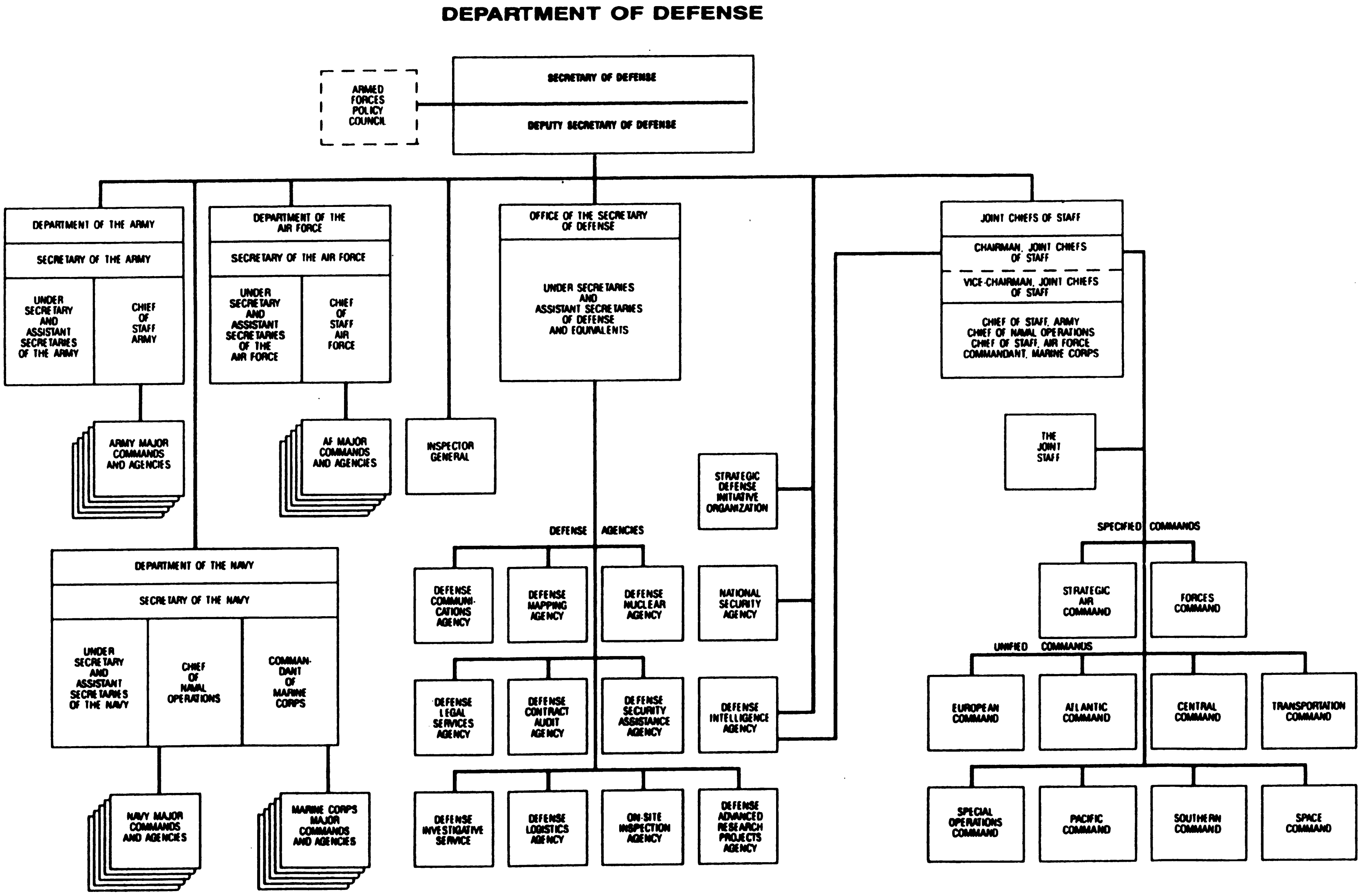
THE DEPARTMENT OF THE NAVY

The Department of the Navy (see organizational chart, figure 1-2) is headed by the Secretary of the Navy, also a civilian, appointed by the President with the advice and consent of the Senate. The Secretary of the Navy is responsible to the Secretary of Defense for the operation of the department. The Assistant Secretary of the Navy (Research, Engineering, and Systems) is responsible to the Secretary of the Navy for all matters pertaining to research, development, engineering, test, and evaluation within the department, including appropriations.

The Department of the Navy and the Department of Defense, of course, are constrained by the Congress, through the budget process, as to what weapons systems they can develop and procure.

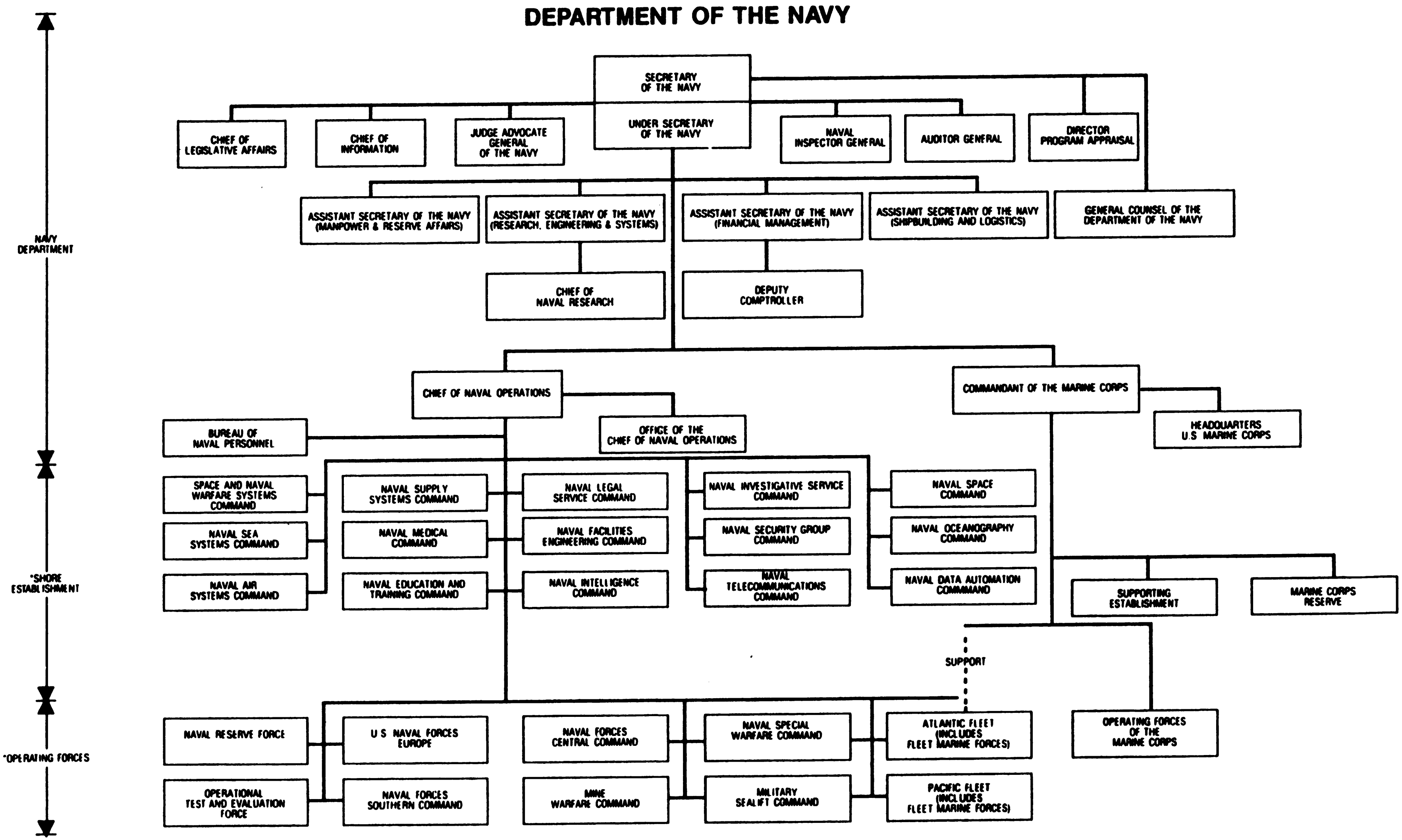
THE SHIPBOARD WEAPONS DEPARTMENT OR COMBAT SYSTEMS DEPARTMENT

The shipboard organization, whether called a weapons department or combat systems department, consists of the personnel who operate and


DEPARTMENT OF DEFENSE
ARMED FORCES POLICY COUNCIL
SECRETARY OF DEFENSE
DEPUTY SECRETARY OF DEFENSE
DEPARTMENT OF THE ARMY
SECRETARY OF THE ARMY
UNDER SECRETARY AND ASSISTANT SECRETARIES OF THE ARMY
CHIEF OF STAFF ARMY
ARMY MAJOR COMMANDS AND AGENCIES
DEPARTMENT OF THE AIR FORCE
SECRETARY OF THE AIR FORCE
UNDER SECRETARY AND ASSISTANT SECRETARIES OF THE AIR FORCE
CHIEF OF STAFF AIR FORCE
AF MAJOR COMMANDS AND AGENCIES
INSPECTOR GENERAL
OFFICE OF THE SECRETARY OF DEFENSE
UNDER SECRETARIES AND ASSISTANT SECRETARIES OF DEFENSE AND EQUIVALENTS
JOINT CHIEFS OF STAFF
CHAIRMAN, JOINT CHIEFS OF STAFF
VICE-CHAIRMAN, JOINT CHIEFS OF STAFF
CHIEF OF STAFF, ARMY
CHIEF OF NAVAL OPERATIONS
CHIEF OF STAFF, AIR FORCE
COMMANDANT, MARINE CORPS
THE JOINT STAFF
DEPARTMENT OF THE NAVY
SECRETARY OF THE NAVY
UNDER SECRETARY AND ASSISTANT SECRETARIES OF THE NAVY
CHIEF OF NAVAL OPERATIONS
COMMANDANT OF MARINE CORPS
NAVY MAJOR COMMANDS AND AGENCIES
MARINE CORPS MAJOR COMMANDS AND AGENCIES
DEFENSE AGENCIES
DEFENSE COMMUNICATIONS AGENCY
DEFENSE MAPPING AGENCY
DEFENSE NUCLEAR AGENCY
DEFENSE LEGAL SERVICES AGENCY
DEFENSE CONTRACT AUDIT AGENCY
DEFENSE SECURITY ASSISTANCE AGENCY
DEFENSE INVESTIGATIVE SERVICE
DEFENSE LOGISTICS AGENCY
ON-SITE INSPECTION AGENCY
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
STRATEGIC DEFENSE INITIATIVE ORGANIZATION
NATIONAL SECURITY AGENCY
DEFENSE INTELLIGENCE AGENCY
SPECIFIED COMMANDS
STRATEGIC AIR COMMAND
FORCES COMMAND
UNIFIED COMMANDS
EUROPEAN COMMAND
ATLANTIC COMMAND
CENTRAL COMMAND
TRANSPORTATION COMMAND
SPECIAL OPERATIONS COMMAND
PACIFIC COMMAND
SOUTHERN COMMAND
SPACE COMMAND

DATE: APRIL 1987

Figure 1-1.—Organizational chart of the Department of Defense.


DEPARTMENT OF THE NAVY
SECRETARY OF THE NAVY
UNDER SECRETARY OF THE NAVY
CHIEF OF LEGISLATIVE AFFAIRS
CHIEF OF INFORMATION
JUDGE ADVOCATE GENERAL OF THE NAVY
NAVAL INSPECTOR GENERAL
AUDITOR GENERAL
DIRECTOR PROGRAM APPRAISAL
ASSISTANT SECRETARY OF THE NAVY (MANPOWER & RESERVE AFFAIRS)
ASSISTANT SECRETARY OF THE NAVY (RESEARCH, ENGINEERING & SYSTEMS)
ASSISTANT SECRETARY OF THE NAVY (FINANCIAL MANAGEMENT)
ASSISTANT SECRETARY OF THE NAVY (SHIPBUILDING AND LOGISTICS)
GENERAL COUNSEL OF THE DEPARTMENT OF THE NAVY
CHIEF OF NAVAL RESEARCH
DEPUTY COMPTROLLER
CHIEF OF NAVAL OPERATIONS
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
COMMANDANT OF THE MARINE CORPS
HEADQUARTERS U.S. MARINE CORPS
BUREAU OF NAVAL PERSONNEL
SPACE AND NAVAL WARFARE SYSTEMS COMMAND
NAVAL SEA SYSTEMS COMMAND
NAVAL AIR SYSTEMS COMMAND
NAVAL SUPPLY SYSTEMS COMMAND
NAVAL MEDICAL COMMAND
NAVAL EDUCATION AND TRAINING COMMAND
NAVAL LEGAL SERVICE COMMAND
NAVAL FACILITIES ENGINEERING COMMAND
NAVAL INTELLIGENCE COMMAND
NAVAL INVESTIGATIVE SERVICE COMMAND
NAVAL SECURITY GROUP COMMAND
NAVAL TELECOMMUNICATIONS COMMAND
NAVAL SPACE COMMAND
NAVAL OCEANOGRAPHY COMMAND
NAVAL DATA AUTOMATION COMMAND
SUPPORTING ESTABLISHMENT
MARINE CORPS RESERVE
SUPPORT
NAVAL RESERVE FORCE
OPERATIONAL TEST AND EVALUATION FORCE
U S NAVAL FORCES EUROPE
NAVAL FORCES SOUTHERN COMMAND
NAVAL FORCES CENTRAL COMMAND
MINE WARFARE COMMAND
NAVAL SPECIAL WARFARE COMMAND
MILITARY SEALIFT COMMAND
ATLANTIC FLEET (INCLUDES FLEET MARINE FORCES)
PACIFIC FLEET (INCLUDES FLEET MARINE FORCES)
OPERATING FORCES OF THE MARINE CORPS
NAVY DEPARTMENT
*SHORE ESTABLISHMENT
*OPERATING FORCES

*ALSO INCLUDES OTHER DESIGNATED ACTIVITIES NOT SHOWN ON THE CHART WHICH ARE UNDER THE COMMAND OR SUPERVISION OF THE ORGANIZATIONS DEPICTED

Figure 1-2.—Organizational chart of the Department of the Navy.

maintain the ship's weapons systems. (Figure 1-3 shows examples of typical shipboard combat systems departments.) These same people are the source of many necessary alteration and development recommendations for improving the systems. They should be encouraged to submit any idea they may have for consideration.

NAVSEA

The Naval Sea Systems Command (NAVSEA), under the Chief of Naval Operations, provides material support for shipboard weapons systems. You will find a NAVSEA office, staffed with engineers and technicians, in every homeport and in many other locations around the world that our ships frequent. These offices are an invaluable resource of weapon system maintenance and repair expertise. They also perform or oversee all ORDALTS. Your chief should become well acquainted with these people.

SOURCES OF FURTHER TRAINING

Many different opportunities are available for both officers and enlisted personnel to learn about naval weapons. The following sources, however, are the most commonly used. They are by no means all inclusive.

CORRESPONDENCE COURSES

There is a Navy correspondence course covering almost every facet of naval weapons. They are readily available by mail through your career counselor or personnel support detachment (PSD).

TECHNICAL MANUALS

Every weapons system and system component are covered by a technical manual called an OP (ordnance publication). These manuals are intended for the trained operator and/or maintenance person and are usually very technical in nature. They also contain sections titled, "General Description" and "General Functional

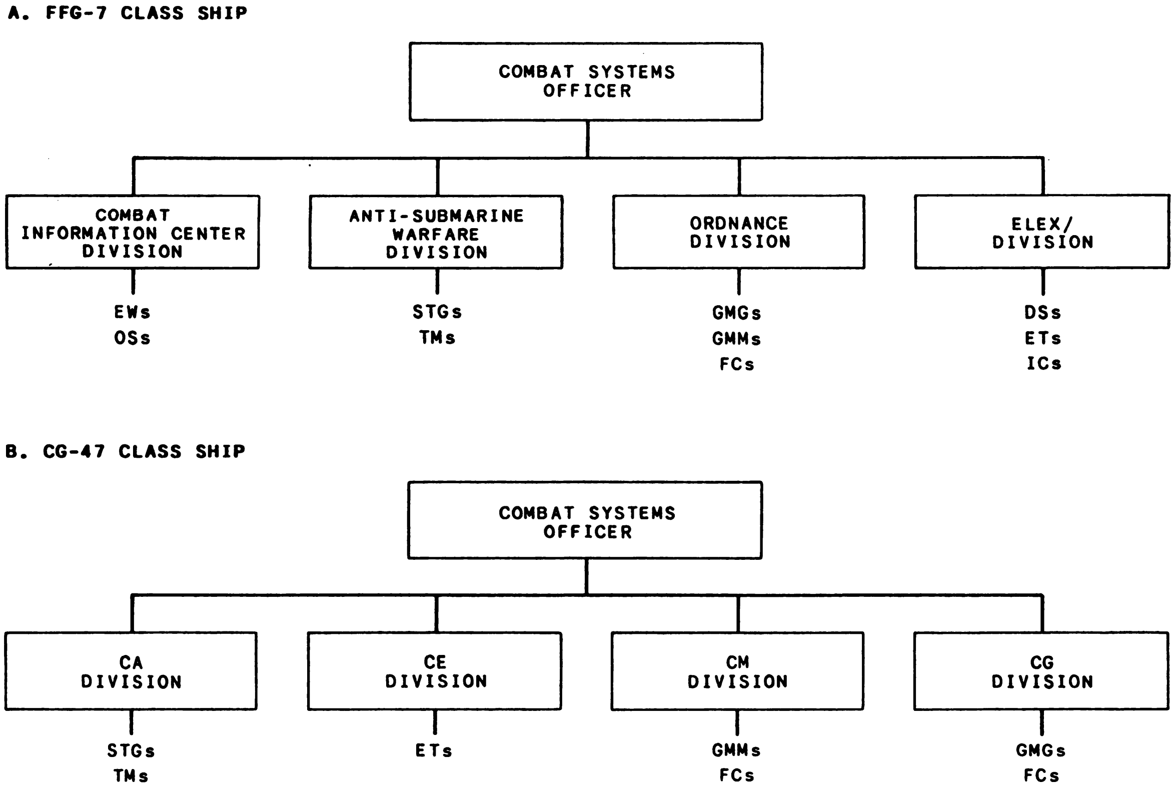


Figure 1-3.—Typical combat systems departments showing the ratings assigned to each division. A. FFG-7 Class ships. B. CG-47 Class ships.

Description," which can be very helpful in understanding the equipment. OP-0 is a listing of all OPs which can be used to identify the publications covering any area in question.

SCHOOLS

Enlisted personnel normally attend class A and C schools before they are sent to a ship to maintain ordnance equipment. These schools, especially class C schools, are very in-depth and produce highly competent technicians. Officers, on the other hand, attend schools that teach them to employ and, to some degree, operate the equipment. Gunnery Officer School, for example, teaches future gunnery officers not only about ammunition accountability but also how to act as "Director Officer," who directs gunfire and operates the director.

Fleet training centers, located in most major stateside ports, offer many different operator and maintenance courses, ranging in length from one day to several weeks. These schools are a valuable resource for training yourself and your men. These schools should be used to the fullest possible extent.

OJT

On-the-job training is the time honored naval tradition of learning as you go. This works very well for tasks that are not highly technical or immediately critical in nature. Be careful of what training you assign to OJT; use schools whenever possible.

ORDNANCE SAFETY PRECAUTIONS

Ordnance safety is of obvious importance to everyone working with or around explosives. Safety precautions are found in just about every publication even remotely associated with ordnance. The primary sources of safety regulations is limited to four publications:

NAVSEA OP-4 AMMUNITION AFLOAT. OP-4 covers all safety precautions pertaining to ordnance handling and storage aboard ship.

NAVSEA OP-5 AMMUNITION AND EXPLOSIVES ASHORE. OP-5 covers all safety precautions pertaining to ordnance handling and storage at shore stations.

NAVSEA OP-3347 US NAVY ORDNANCE SAFETY PRECAUTIONS. This is a supplemental publication showing the results of unsafe handling procedures with graphic illustrations of explosive mishaps.

OPNAV 5100 (series). These are general, Navywide, safety precautions covering a wide range of subjects in addition to ordnance safety.

SUMMARY

So far we have discussed the basic language of the ordnance world, how ordnance is identified, who is responsible for ordnance development, procurement, and maintenance as well as some sources of ammunition safety precautions. In the following chapters, we will build on this base of knowledge. In the next two chapters we will expound further on the elements that go together to make up a functioning shipboard weapons system, as well as some of the scientific principles they are based on. The remainder of this text is devoted to describing the individual systems actually in the fleet today.

CHAPTER 2

ELEMENTS OF NAVAL WEAPONS SYSTEMS

In this chapter, we are going to expand upon the terms we discussed in chapter 1. First, we will discuss the history of naval weapons; then we will describe each component in more detail as we explain how they work together to make up a functioning weapon system.

EVOLUTION OF NAVAL WEAPONS

A weapon system, as defined in chapter 1, is the combination of a weapon and the equipment used to bring the destructive power of the weapon to bear against the enemy. Shipboard weapons, crude as they may have been, have existed for centuries. Earlier systems were less complex (and less destructive) than those currently in use; but they were weapons systems, nonetheless.

GUNS

Before guns were invented, the ship itself was used to sink or damage an enemy ship by ramming. After ramming, the two crews would engage in hand-to-hand combat until one side overcame the other. This tactic had been used with varied success as late as World War II; but of course, this is not the preferred method of engaging the enemy. The early development of the gun enabled ships to engage at slightly longer ranges prior to ramming or boarding. As gun technology progressed, the accurate engagement at greater distances and with greater destructive power became possible, with the greatest advances coming in the first part of the twentieth century. At the end of World War II, naval guns were engaging targets at ranges of 40,000 yards and beyond.

FUZES

Much of the effectiveness of modern weapons has been due to the development of a safe and reliable fuze. A fuze is a mechanical or electrical device used to detonate an explosive-filled projectile. Impact fuzes were developed soon after the cannon, but were not refined to the safe or reliable point until the mid-nineteenth century. We now have a vast array of different fuzes (proximity, point detonating, mechanical time, etc.), which function safely and with a high degree of reliability.

UNDERWATER WEAPONS

Underwater weapons, such as mines and torpedoes, have also been around much longer than most people realize. Mines (formerly called torpedoes) have been used as far back as the American Revolution and are still widely used today to deny or restrict the use of the vital waterways. The mining of North Vietnamese harbors by the U.S. and the mining of the Persian Gulf by Iran are current examples of the effective use of mines.

Torpedoes, originally designed in the late nineteenth century to be fired from small, fast boats, were fired from submarines with deadly effect in World Wars I and II. Torpedoes, now launched from almost every type of platform, are highly effective against both surface and subsurface targets.

FIRE CONTROL

The improvements in gun ranges mentioned earlier could make them effective only if they were adequately directed or aimed. The evolution of modern fire control began with the invention of the fixed gun sight in the early nineteenth century, and continued with the development of movable sights in the 1840s. Telescopic sights, with drift and windage compensation, were developed in the 1850s and 1860s; then came directors with optical range finders in the World War I period. Fire control took a major step forward during World War II with the incorporation of radar as a detecting and tracking element.

With the advent of the submarine at the beginning of the twentieth century came the invention of sonar. Early sonar was nothing more than an underwater listening device that gave the operator a rough idea of a target's bearing and range. The active-type (ping) of sonar was developed later enabling the detection of targets that did not give off detectable noise. Though similar in principal to radar, sonar does not have the same range or accuracy. Both radar and sonar are now core elements in modern fire control systems.

ROCKETS AND MISSILES

Developed centuries ago by the Chinese, rockets have been used to deliver explosive payloads throughout military history. World War II saw the adaptation of entire ships for use as rocket launching platforms. Rocket technology evolved into one of the most deadly of naval weapons, the guided missile. Guided missiles were first developed for military use by the Germans during World War II. Their V-2 Rocket was the first truly **guided** missile. German scientists and captured technology quickly propelled the United States into the missile age.

With this brief exploration of the history of modern weapons, we will now discuss the major components that make up weapons and weapons systems.

WEAPONS SYSTEM REQUIREMENTS

Fire control is problem solving. The problem is hitting and destroying a target with the ship's weapons. Solutions must be found for directing a destructive device to one of the three types of targets: surface, subsurface, and air. The destructive device could be a missile, gun projectile, or torpedo.

To accurately deliver a weapon on target, we must know the target's location and speed. Many air targets today travel at speeds well over the

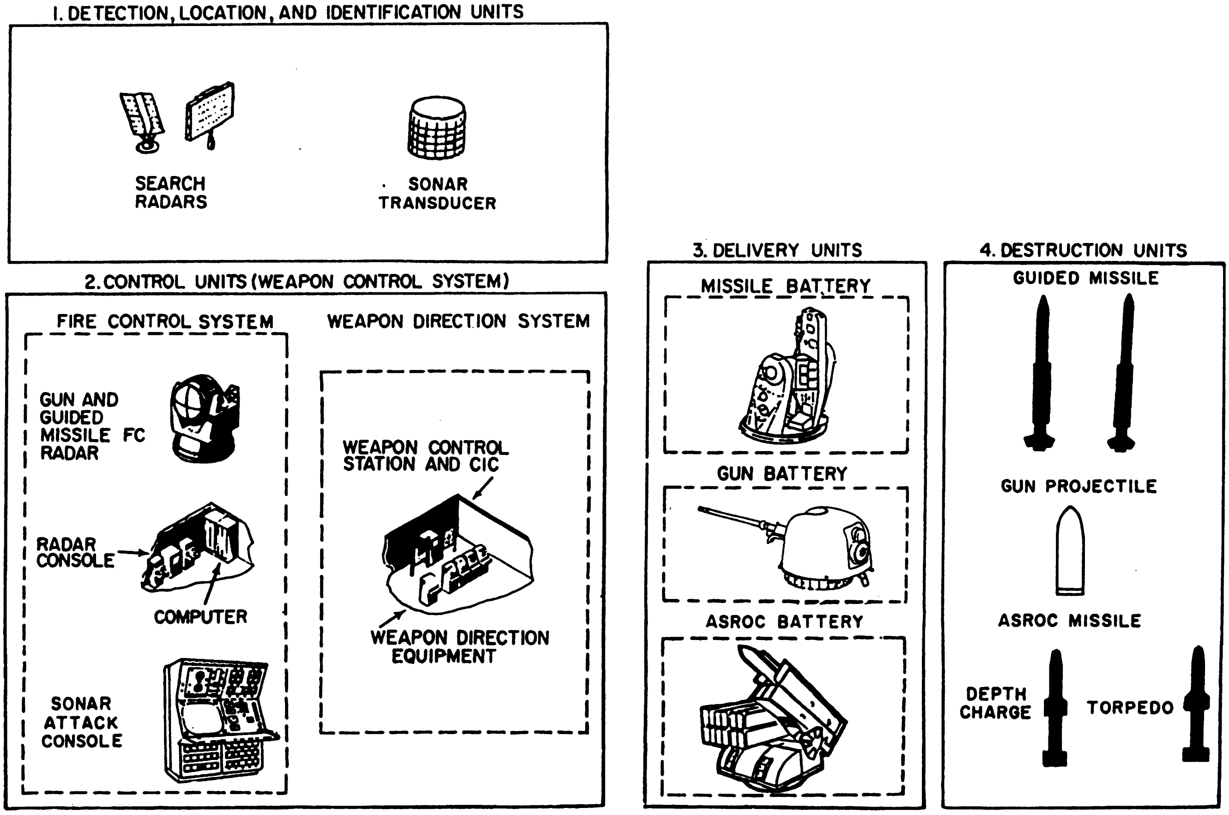


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Figure 2-1.—The weapons system concept.

speed of sound and are capable of delivering weapons from great ranges. Targets such as these must be engaged before they can launch weapons. A weapon is most effective against these targets when used as part of a weapons system. A weapons system (fig. 2-1) is a combination of several elements that perform the tasks of (1) detecting the target, (2) aiming the delivery unit(s), (3) delivering or initiating delivery of the weapon, and (4) destroying the target. These tasks are performed by the following units:

1. **DETECTION UNITS**. Radar and sonar find the target.
2. **CONTROL UNITS**. Fire control systems, with the use of target and own-ship's data, accurately aim the weapon delivery unit so that the weapon can be launched or fired to intercept the target.
3. **DELIVERY UNITS**. These are the missile launchers, gun mounts, and rocket launchers that fire or launch the weapon.
4. **DESTRUCTION UNITS**. These are the missiles, projectiles, or torpedoes that actually destroy the target.

DETECTION UNITS

The first step toward destroying a target is detection. This includes determining range, velocity, and whether or not the target is hostile. Ideally, detection should take place at maximum range to allow time for an effective defense in the case of a hostile contact.

The Navy uses several different types of systems to detect targets. Different types of targets, operating in the three different environments (air, surface and subsurface), require detection units that are effective in each element. The principal detecting devices now used in the fleet include the following:

1. Radar
2. Sonar
3. EW (Electronic Warfare)
4. MAD (Magnetic Anomaly Detection)

Each of these units is highly effective in detecting targets in a specific environment. Radar is the primary device used to detect both air and surface targets, but is useless for finding submerged submarines. Sonar, on the other hand, is most effective in locating subsurface targets. Sonar can also be used to detect surface craft, but it is totally inadequate for the detection of aircraft. We will now discuss each of these units in more detail. As we do, we will describe the basic principles of operation, as well as how they are employed and what data they provide.

Radar

Since its inception in the late 30s and early 40s, radar has developed into a very necessary element of both detection and control units. Modern Navy radars can supply a target's range, bearing, and altitude. All this data is necessary in the final solution of the fire control problem. Now, let's discuss how radar works.

Every ship has a whistle. Suppose the whistle sounded a short, sharp blast a mile or two from another vessel. If you listened carefully after the blast sounds, you would hear an echo reflected back from the other vessel. If you know the speed of sound, and can measure accurately with a stopwatch the time elapsed between the whistle blast and the echo, you can easily determine the range to the other vessel. This is a simple application of the distance, rate, and time equation. You'll notice one variation, however; the product of the rate and time must be divided in half to account for the two-way travel of the sound wave.

If, instead of a whistle, you use a powerful radio transmitter, and, instead of your ears, you use a radio receiver, you have the essentials of radar. The name **radar** is an acronym for Radio Detection and Ranging. Figure 2-2 shows one transmitted pulse and one reflected echo as they travel between own ship and the target.

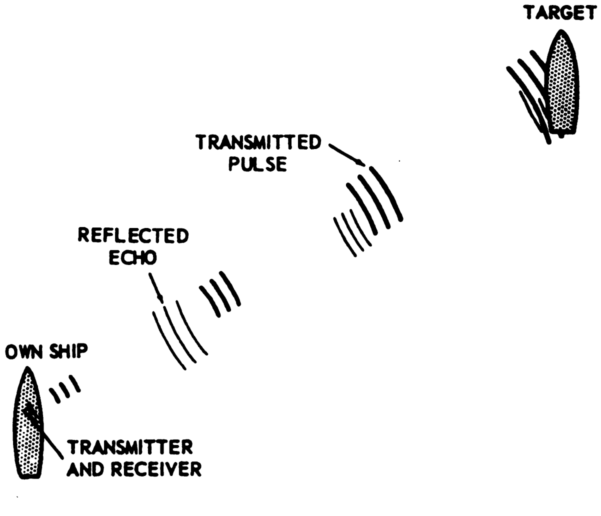

Figure 2-2.—Principle of radar.

We will not discuss the principles of radar any further in this text. We will, however, cover the application of radar in specific detection and control systems. For further information on the principles of radar, refer to NAVEDTRA 172-18-00-84, Navy Electricity and Electronics Training Series (NEETS), Module 18, *Radar Principles.*

Sonar

Radar cannot be used underwater because water absorbs radio waves. However, water does conduct sound better than air; and for this reason, the Navy uses sound as a means to detect submarines.

The function of sonar is much like that of radar. Instead of a radio transmitter and receiver, you have a transducer and a **stack**. The transducer (fig. 2-3) acts much like the antenna of a radar, since it both emits the signal and collects the echo. The stack is the console that the operator monitors. While it is the source of the signal emitted from the transducer, it contains the equipment that analyzes and displays the echo.

The speed of sound waves traveling through water is controlled by three conditions: (1) water temperature, (2) water pressure (caused by depth), and (3) water salinity. Water temperature is the most important factor. It influences sound wave direction and shape to a large degree and can vary greatly over a small area. Figure 2-4 illustrates how sound waves may respond to different water characteristics.

When using sound (pinging) to find targets, a sonar system is said to be in the **active** mode. Sonar can also be used in the **passive** mode (without the use of sound waves). You are, in effect, turning off the sound producing transmitter and listening through the receiver for the sound of a submarine. Submarines and ships are detectable by their propeller and machinery noises. Modern passive sonar has proved to be very effective.

This concludes our discussion of the principles of sonar. We will be discussing the application of both active and passive sonar in chapter 8 when we talk about target detection. For further information and study on the principles of sound and sonar, refer to NAVEDTRA 053-01-45-82, *Sonar Technician 3 & 2*, Module 1.

Electronic Warfare (EW)

Electronic warfare has evolved into a highly reliable means of detecting and identifying targets by the electromagnetic radiations they emit. Every radar, whether it be search, guidance, or fire control, emits electromagnetic radiation when operating. Each individual system uses a

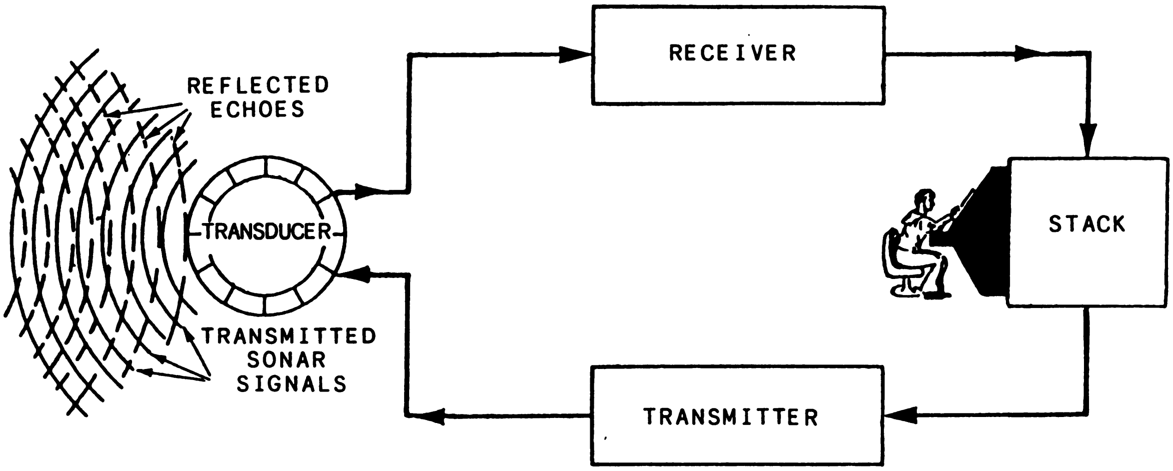

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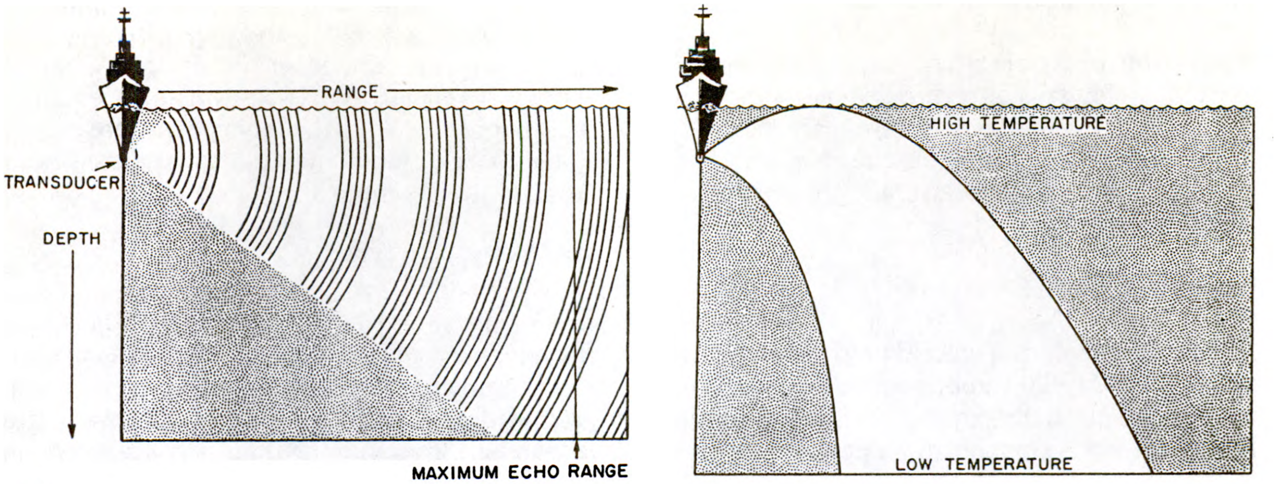
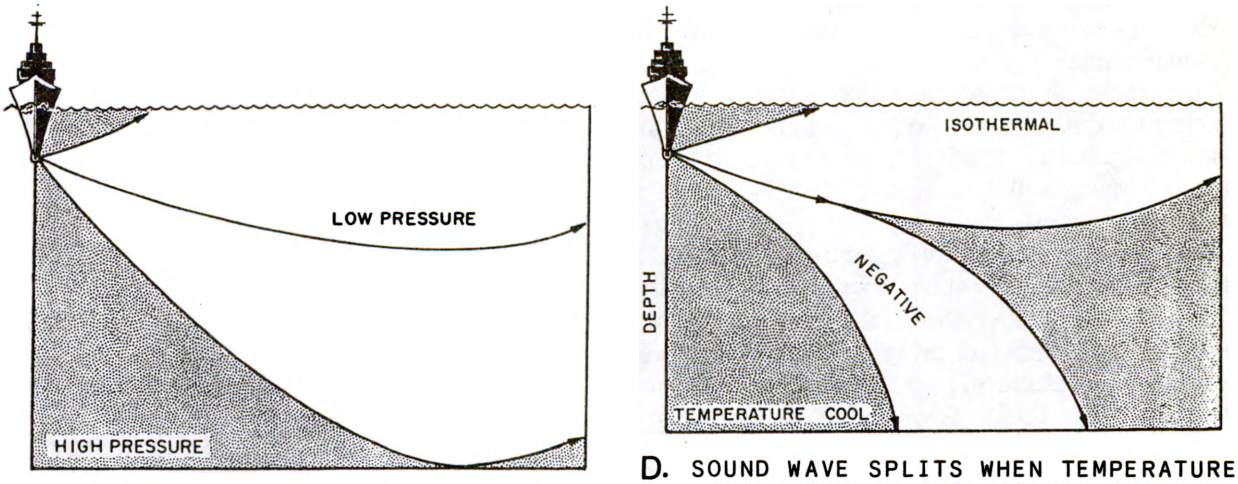
Figure 2-3.—A simplified sonar system.



A. SOUND TRAVEL IN WATER OF CONSTANT TEMPERATURE.

B. A REFRACTED SOUND BEAM.



C. PRESSURE TENDS TO BEND THE SOUND BEAM UPWARD.

D. SOUND WAVE SPLITS WHEN TEMPERATURE IS UNIFORM AT SURFACE AND COOL AT BOTTOM.

Figure 2-4.—Sound wave reactions to different water characteristics.

particular frequency or combination of frequencies. Once the radiation frequency of a particular system is known, it can be easily identified when received by our EW equipment. Since certain systems are peculiar to certain types of vessels, the emitting platform can also be identified. EW equipment can supply information about the type of transmitter, probable source, approximate range, and bearing.

What we have just described is what is called ESM (electronic support measures) or the passive side of electronic warfare. On the other side of the house is ECM (electronic countermeasures). ECM involves the active interference or deception of the enemy's electronic emissions. This process includes jamming, which is emitting signals that interfere with an enemy's transmissions. False signal generation (i.e., an amphibious ship radiating signals that are normally associated with an aircraft carrier) and firing chaff (using a projectile that explodes—producing a large cloud of metallic particles) serve to mislead enemy radars as to your exact location. These tactics were used effectively by the British in the Falklands.

Much of the information on electronic warfare is highly classified and cannot be discussed in this text. We hope, however, to give you enough information to help you understand the basic concepts.

Magnetic Anomaly Detection (MAD)

Any ferrous object will distort the earth's magnetic field. This distortion can be detected by a sensitive device—Magnetic Anomaly Detection (MAD) equipment. This equipment is either towed by, or carried in, an aircraft to search for submarines.

CONTROL UNITS

Once a target is detected and identified as hostile, the ship's weapons must be effectively brought to bear to destroy it. This is accomplished through use of a fire control system. As defined in chapter 1, a fire control system consists of the electronic and mechanical equipment used to track targets, to compute the projectile intercept point with the target, and to generate from this data the necessary train and elevation orders for the delivery units.

In the case of most guided missiles, the fire control radar is used to relay guidance information to the missile in flight. These functions and many others will be discussed further in later chapters.

The heart of a fire control system is the director, computer, stable element, and radar. These are all components of a fire control system used to engage surface and air targets. Now, let's expand our definition to include the ship's underwater battery (UB). These systems also require similar components to track targets, to compute weapon-to-target intercept points, and to generate delivery system control orders.

The ship's sonar, in addition to being a detection system, supplies data to the attack console. The attack console is similar to a combination of a radar console and a fire control computer. It supplies a display for tracking the target and combines the target and own-ship's data to compute a fire control solution. The output is supplied to the underwater weapons in the form of train and elevation orders to an ASROC launcher, and as target data to a torpedo to determine a search pattern.

A control system also includes the interface units that take data from the detection unit and supply it to the fire control system. These interface units are used by operators in the Combat Information Center (CIC) to assign targets to fire control systems for them to track and engage. CIC is the nerve center of the ship. In normal combat operations, all command and control functions are initiated from here.

As we build on these definitions, you can see that prior to actually putting a gun or missile launcher out on the beam for firing at a target, there is a very involved sequence of events that must happen to get to that point. In actuality, with state- of-the-art equipment, these events take only seconds to accomplish.

DELIVERY UNITS

Basically, a delivery unit is used to launch or fire a destructive unit. To be effectively employed, a weapon must be aimed at a target or programmed to function in a certain way after launching. Programming is initially accomplished before launch—using data from the fire control system that is fed to the weapon through the delivery system. Some weapons can have their programming updated after launching, while others cannot. Aiming the weapon is the act of positioning the delivery device for firing. An example that uses both aiming and programming is a missile launcher. The missile is put on the rail and positioned so that when launched it will be heading toward an intercept point with the target. As the missile sits on the rail, it is fed target data that is used to guide the missile after it is fired. The missile may or may not receive additional data after it is launched.

DESTRUCTION UNITS

The end purpose of detection, control, and delivery units is to cause the destruction unit to intercept or pass near the target. It is the function of the destruction unit to destroy or inflict maximum damage on the target.

The destructive unit takes many different forms. Most are an explosive filled device; (i.e., projectile, missile, torpedo) with a fuze installed to initiate detonation at the preferred time. For some weapons the preferred time is the moment of contact. Some need to penetrate prior to detonation, while others need only pass near the target.

The exact make up and use of the most common types of weapons, including fuze types, will be discussed further in later chapters.

THE COMBAT SYSTEMS CONCEPT

Modern war ships have gone to the **combat systems department**- type of organization. This means that all the personnel and equipment used to detect and destroy a target are in the same department. In the older **weapons department**-type of organization, the detecting function was handled by the operation's department. The remaining functions were accomplished by the men and equipment in the weapons department. Some of the older ships may still be set up under the old doctrine, but they are becoming fewer each year. The advantage of the combat systems department organization is that everyone involved is part of the same team all the time. This means they can be trained as a team—from CIC to the gun house.

SUMMARY

In this chapter, we have expounded upon some of the definitions presented in chapter 1 and have provided some background on their history. As you can see, the shipboard weapons system is very complex. In the next chapter, we will discuss some of the basic sciences involved in weapons system technology and define some of the common subassemblies that make up the core of weapons system components.

REFERENCES

Navy Electricity and Electronics Training Series, Module 18, *Radar Principles*, NAVEDTRA 172-18-00-84, Naval Education and Training Program Development Center, Pensacola, Fla., 1984.

Principles of Naval Ordnance and Gunnery, NAVEDTRA 10783-C, Naval Education and Training Program Development Center, Pensacola, Fla., 1974.

Sonar Technician 3 & 2, NAVEDTRA 053-02-45-82, Naval Education and Training Program Development Center, Pensacola, Fla., 1982.

CHAPTER 3

BASIC MECHANISMS IN NAVAL WEAPONS

In this chapter, we will discuss the basic types of mechanisms that are used to power and operate naval weapons systems. This includes hydraulic, electric, and electronic devices as well as mechanical. We will discuss each type of device by the way it is used in a modern naval weapons system. We will discuss operational theories in general to allow you to understand how a mechanism functions. If you desire more information on these operational theories, they are covered in other available training manuals. These references will be notated throughout this chapter.

THE SCIENCE OF PROJECTILE FUZE ARMING AND OPERATION

A projectile fuze is the device that initiates the detonation of high explosive projectiles. As we said earlier, a reliable fuze is one that enables us to detonate the projectile at the most desirable moment. At the same time, however, they must be safe enough to be handled and stored.

INERTIA

All fuze mechanisms depend on certain forces to either start their function (arm) or to keep them functioning. These forces develop either when the projectile is fired, as it spins, when it flies through the air, or at the end of flight (fig. 3-1). They are known respectively as setback, centrifugal force, creep, and impact. Each of these forces is an effect of inertia.

In 1687, Sir Isaac Newton described inertia in his now famous Law of Motion, which says:

> "Every body tends to remain at rest, or in uniform motion in a straight line, unless compelled by external force to change."

All objects are subject to the law of inertia. For our purposes, we will say inertia is an object's resistance to change in motion. A ship that is dead in the water, for example, tends to remain so. The ship will not overcome this tendency without a large effort by its propulsion plant. However, once it is moving it tends to keep moving even when the engines have stopped. It would continue to move in the same direction indefinitely if it were not for obstructions and the friction of the water.

Setback

When the propelling charge of the round fires, the fuze and projectile are at rest. As the hot expanding gases expand, pressure in the chamber builds up and forces the projectile to move forward (fig. 3-1, view A). But because of inertia, the projectile and fuze tend to stay where they are. The effect is the same as what a person feels in an automobile that rapidly accelerates from a dead stop. Your head is thrown back and your body sinks into the seat. This is the effect of inertia trying to keep your body in one place.

Centrifugal Force

When a projectile is fired through a rifled barrel, spin is imparted to it through the rotating band. Spinning develops centrifugal force, which is the tendency to move away from the center of rotation (fig. 3-1, view B).

Creep

Like everything else that moves through the air, a projectile in flight moves against air resistance, which tends to slow it down. The slowing down effect is applied only to the outside of the projectile. Components inside the projectile and fuze are not directly affected and tend to "creep" forward as the projectile slows (fig. 3-1, view C). If you were in your automobile again, consider what would happen if you gently stepped on the brakes. As your car slowly decelerates, you would feel yourself leaning

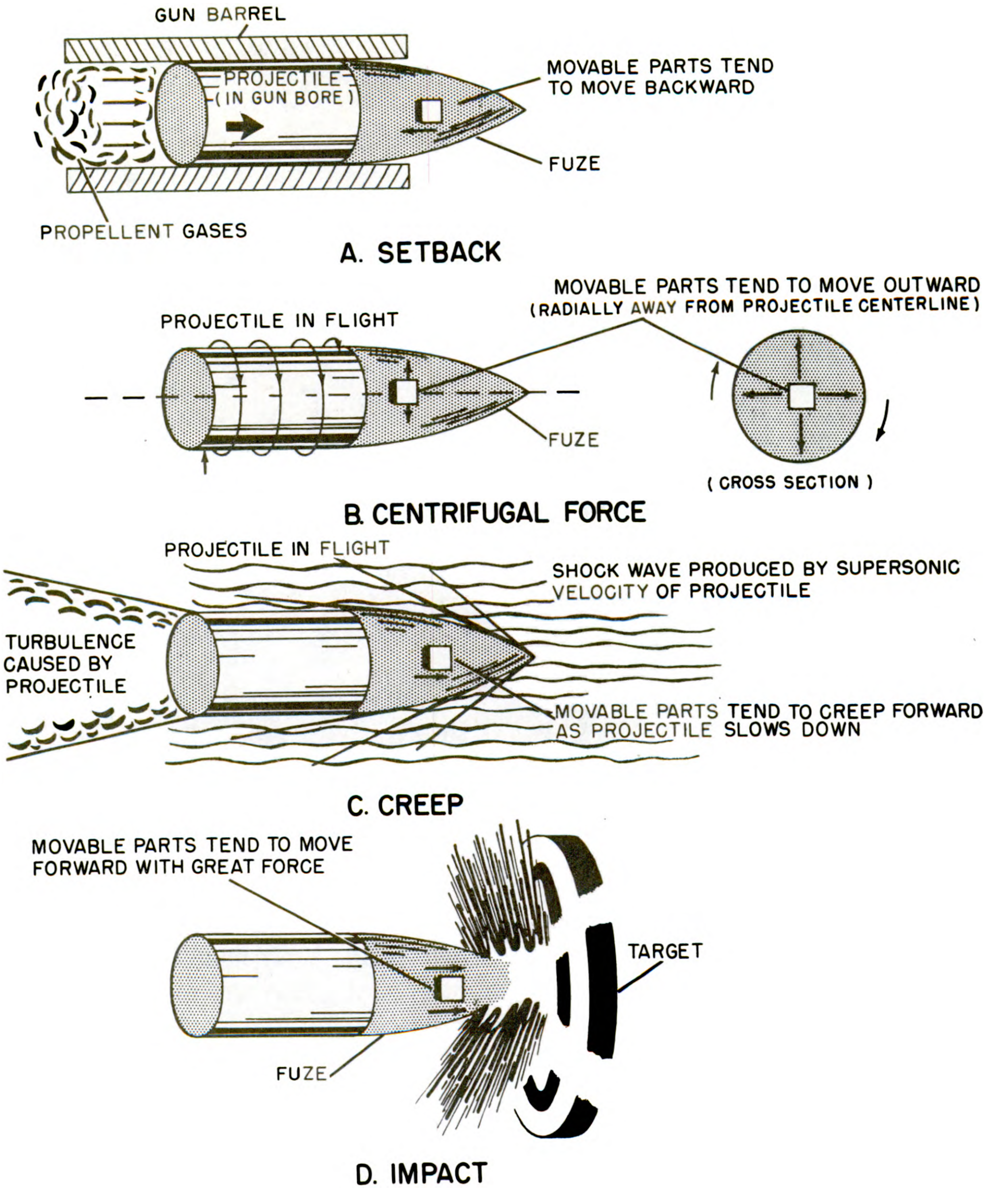

GUN BARREL
PROJECTILE (IN GUN BORE)
MOVABLE PARTS TEND TO MOVE BACKWARD
FUZE
PROPELLENT GASES
A. SETBACK
MOVABLE PARTS TEND TO MOVE OUTWARD (RADIALLY AWAY FROM PROJECTILE CENTERLINE)
PROJECTILE IN FLIGHT
FUZE
(CROSS SECTION)
B. CENTRIFUGAL FORCE
PROJECTILE IN FLIGHT
SHOCK WAVE PRODUCED BY SUPERSONIC VELOCITY OF PROJECTILE
TURBULENCE CAUSED BY PROJECTILE
MOVABLE PARTS TEND TO CREEP FORWARD AS PROJECTILE SLOWS DOWN
C. CREEP
MOVABLE PARTS TEND TO MOVE FORWARD WITH GREAT FORCE
TARGET
FUZE
D. IMPACT

Figure 3-1.—Forces that act on projectiles and fuzes.

forward. Inertia is trying to keep your body moving forward.

Impact

Impact (fig. 3-1, view D) is probably the most obvious application of the principle of inertia to fuzes. When the projectile strikes, it comes to a stop. But the movable parts inside keep right on going. You can use the force developed by this tendency to drive a firing pin into a percussion cap to initiate the explosive train. Though impact and creep are similar, they vary in degree and in how they are used in fuze mechanisms.

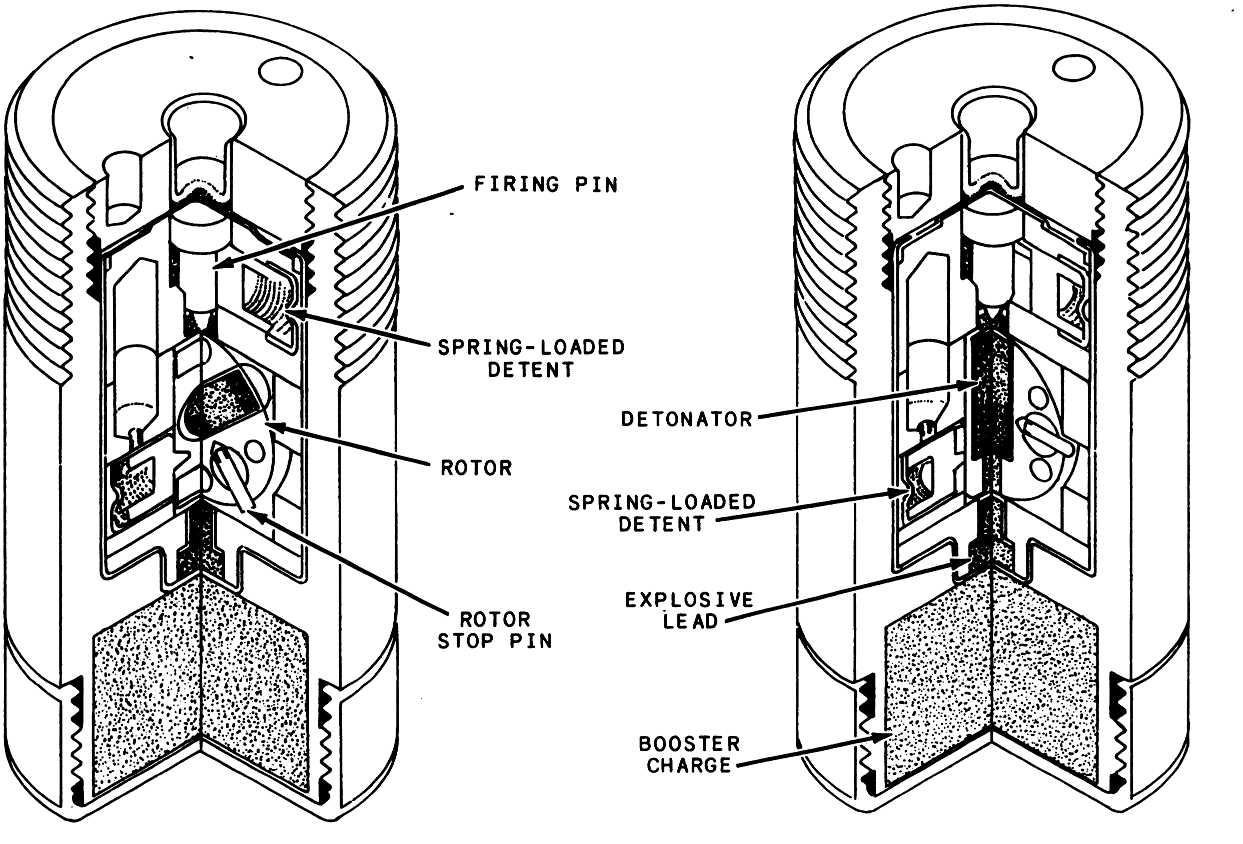
ARMING

The routine handling and storage of projectiles often include a certain amount of jarring. Ammunition is normally moved with a forktruck, a helicopter, and by hand. They are also stored aboard a ship that is constantly moving and vibrating. This means that Navy ammunition must not be so sensitive that these bumps and jars cause them to explode.

To accomplish this, projectile fuzes are designed not to function until after they have been fired or launched. The fuze incorporates a blocking device that physically prevents the firing mechanism from contacting the detonator. To "arm," or make the fuze operational, it must be acted upon by one or more of the different types of inertia. Once fired, the inertial forces begin to build and act on the projectile and fuze. The arming device is constructed so that it will not arm until a certain level of inertial force has acted on it. Given standard powder charges and projectile weights, the time required for these forces to reach a certain level can be determined. This time translates to time of flight which allows us to determine the distance from the delivery unit that we want the fuze to arm. This quality is called boresafe.

To illustrate how inertia is used to arm and operate a projectile fuze, let's look at a typical fuze (fig. 3-2). When the gun is fired, the force of setback moves the internal components of the fuze rearward and locks them against movement. As the projectile moves down the rifled bore, it is imparted rotation through the rotating band, creating centrifugal force. The projectile and fuze body travel through the air, meeting resistance and slowing down because of friction. The inertial force of creep frees the internal components for movement. Centrifugal force then moves the two sets of detents outward, unlocking the firing pin and detonator rotor for movement. Centrifugal force, acting on weights in the rotor, causes the rotor to turn until the detonator is in direct alignment between the firing pin and the booster lead-in. Continued centrifugal force maintains the explosive train in alignment. The fuze is armed. Upon impact, the firing pin is driven into the detonator, initiating the explosive train through the explosive lead to the booster charge. The booster charge detonates the main burster charge.

Many different arrangements are used to arm both gun projectile and missile fuzes. All use the forces of inertia in one way or another. Some are totally mechanical, and some are a combination of mechanical and electrical. We will be discussing



SAFE

ARMED

110.177

Figure 3-2.—Projectile base fuze.

the general function and use of different types of fuzes in chapter 4. For further detailed information on fuze arming and operation, see NAVSEA SW010-AB-GTP-010, *U.S. Navy Ammunition, Historical and Functional Data*.

MECHANICAL DEVICES

The movement and functioning of major systems, such as directors, launchers, and gun mounts, is accomplished, in part, using some basic mechanical devices. We will now discuss the functioning principles and applications of cams, gear trains, and levers.

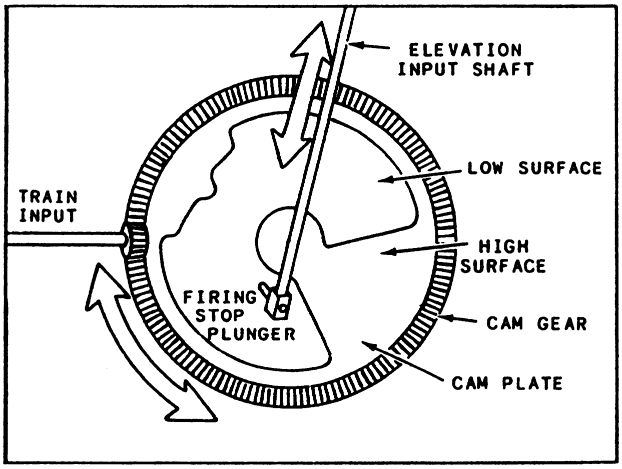


Figure 3-3.—A face cam used in a firing cutout mechanism.

CAMS

A cam is an irregularly shaped device used to transmit motion through a follower. The cam surface contours are determined by the needs of the device it serves. The follower may be used to operate any number of other mechanisms.

As you can see in figure 3-3, a face cam is used as a cutout device for a gun firing circuit. The cam face is contoured to correspond to the ship's firing and nonfiring zones. Each position on the cam plate corresponds to a specific position of gun train and elevation. The low area corresponds to positions in which the gun may be safely fired; the raised area corresponds to the areas where firing would endanger permanent ship's structure. The cam is geared to the train drive to rotate as the gun moves in train. The follower is linked to move across the face of the cam as the gun is moved in elevation. The follower is linked to a switch in the firing circuit that opens when the follower is raised by the high portions of the cam.

The face cam is one of many different styles. There are also barrel cams and edge cams. The barrel cam is similar to the face cam, but is cylindrical in shape, with the cam surface on the inside or outside. Both face and barrel cams are used in firing cutout mechanisms.

An edge cam is one that has the irregular surface machined around its outer edge. They may be stationary, with the follower attached to a nearby moving component, or rotary. Edge cams are used to shift valves, make or break switches,

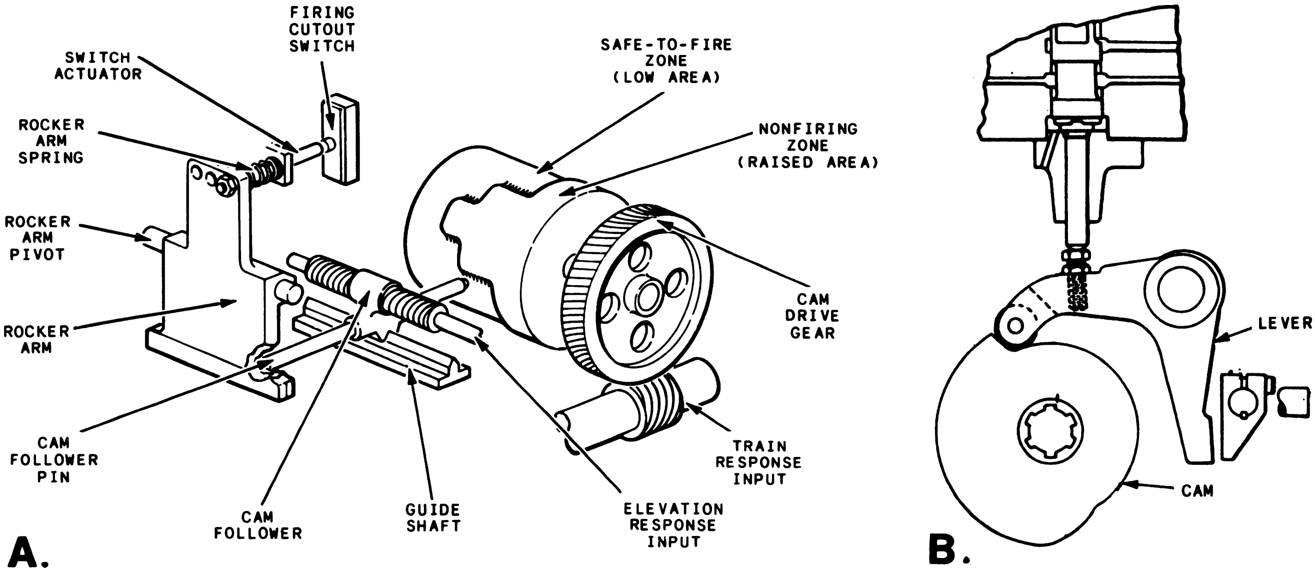


Figure 3-4.—A. A barrel cam used as a firing cutout device in a 5"/54 gun; B. An edge cam positioning a hydraulic valve.

and position other mechanical devices. Figure 3-4 shows some of the uses of cams in ordnance equipment.

GEAR TRAINS

Gears are used in almost all types of ordnance equipment. They are used to change direction of motion, to increase or decrease the speed of applied motion, and to magnify or reduce applied force. Gears also give you positive drive. There can be, and usually is, some slippage in a belt drive. Gear teeth, however, are always in mesh so there can be no slippage. This is true as long as the teeth are in good shape and not worn.

Gears in ordnance equipment are normally not seen. They are usually encased in a gearbox, filled with gear lubricant. You can be sure that gears and gear trains are at the heart of almost every type of machine.

Changing Direction of Motion

Figure 3-5 represents the fundamental concept of reversing direction of rotation with gears. We have two gears in this simple gear train, the drive gear and the driven gear. The drive gear is rotating in a clockwise direction. This turns the driven gear in a counterclockwise direction, reversing the direction of rotation.

This quality is inherent in all gear trains; one gear turning another will always reverse the direction of motion. This is not always the desired result. To overcome this, we insert an idler gear between the drive gear and the driven gear as shown in figure 3-6. The idler reverses the direction of motion coming from the drive gear. This allows the driven gear to be turned in the same direction as the drive gear.

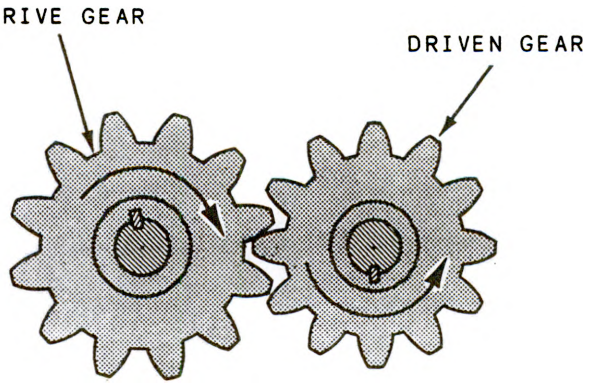


Figure 3-5.—Gears used to reverse the direction of rotation.

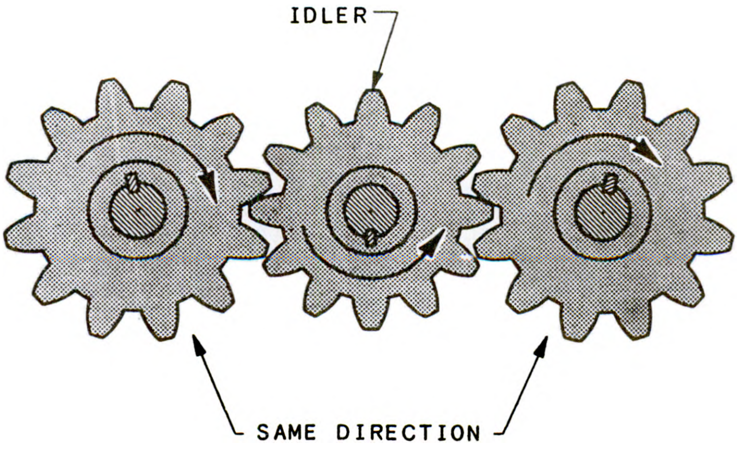


Figure 3-6.—The function of an idler gear.

Another form of direction change performed by gear trains is a change in angular direction. Figure 3-7 illustrates some of the different gear configurations used to change angular direction of motion. The first, and most common, is the bevel gear (fig. 3-7, view A). Bevel gears can be used to turn just about any angle. There are several different forms of bevel gears. The difference is in how the teeth are cut. The rack and pinion-type gear (fig. 3-7, view B) is used in cases where linear motion is desired. The rack and pinion gear is used in the rammer mechanism in both the 5″/38 and 5″/54 gun mounts.

Worm gears (fig. 3-7, view C) are a special type of gear train. They have a unique property that makes them very useful for train and elevation drive trains and ammunition hoists. A worm gear can transmit motion in only one direction, through the worm. In application, this means that should you lose power half way through a hoist cycle, your hoist and ammunition will not "free-fall" back to the bottom of the hoist. The 3″/50 gun mount does not use a worm gear drive in its elevation power train. The guns must be manually pinned in place with a safety bolt device when the drive motor is secured. If they are not pinned, they will free-fall, since they are much heavier in the rear. This unintentionally points the gun straight up in the air. This is of obvious importance if you have to perform a maintenance check that involves getting under the rear of the gun. All other guns use worm gears.

Figure 3-7, view D, shows a pinion and an internal gear. Either can serve as the drive gear. This configuration is used in most missile launcher and gun mount train drives. The internal gear is

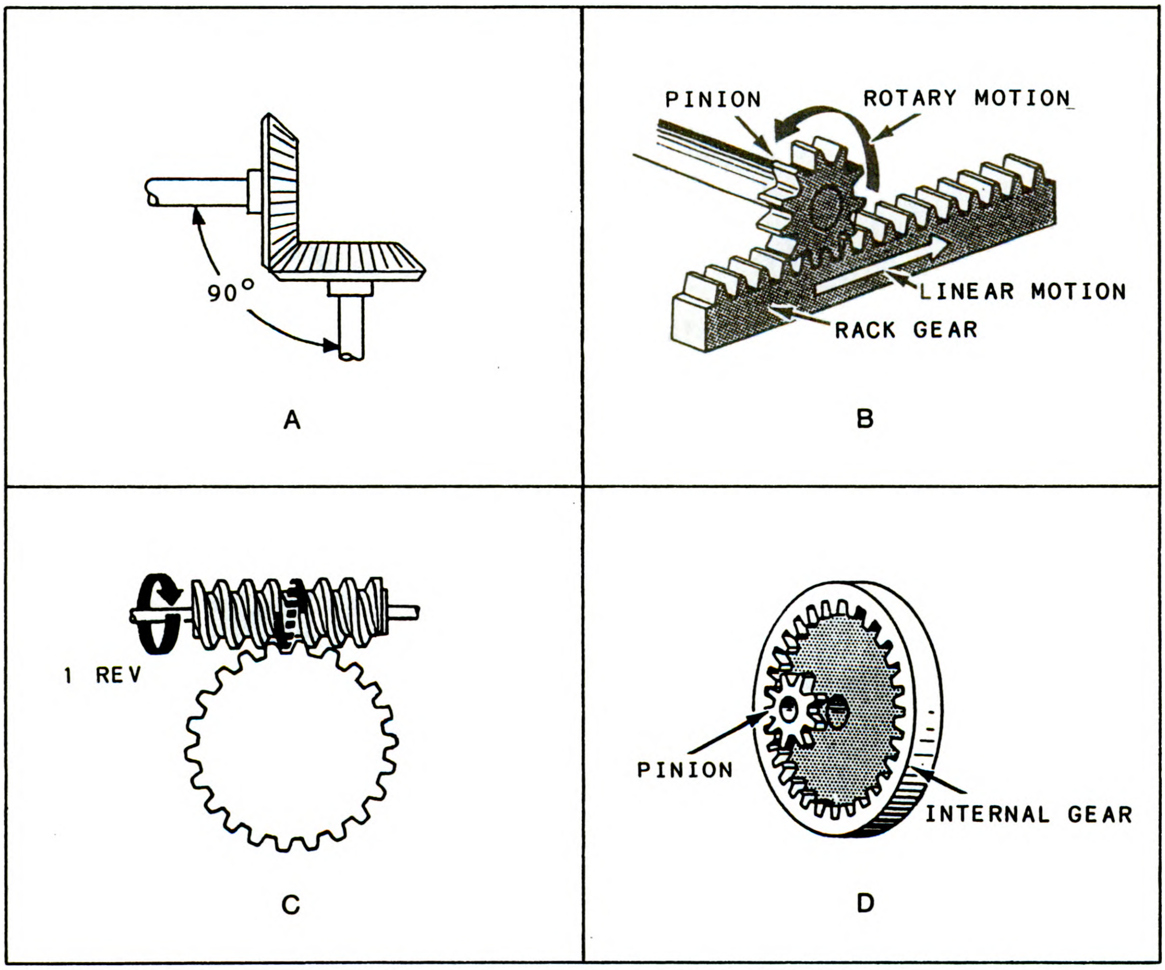


Figure 3-7.—Gear configurations.

mounted stationary in the stand, while the pinion is part of the mount or launcher. The train drive motor transmits motion through a worm gear to the pinion, which walks around the inside of the internal gear, moving the mount or launcher with it.

Changing Speed

Most hydraulic equipment is driven by a 440-vac constant speed electric motor. To be efficient, these motors have to spin at very high speeds. To be usable for driving a hydraulic pump or anything else, the output speed of the motor must be reduced. This is accomplished through reduction gears. The reduction gears are located in an oil-filled encasement, which normally appears to be part of the drive motor housing.

Figure 3-8 will help you understand how this is possible. Wheel A has 10 teeth, which mesh with the 40 teeth on wheel B. Wheel A will have to rotate four times to cause wheel B to make one rotation. Wheel C is fixed rigidly to the same shaft as wheel B. Therefore, wheel C makes the same number of revolutions as wheel B. However, wheel C has 20 teeth, and meshes with wheel D, which has 10 teeth. This causes wheel D to rotate twice for every one revolution of wheel C. If you rotate wheel A at a speed of four revolutions per second, wheel B will rotate one revolution per second. Wheel C also moves one revolution per second, turning wheel D at a speed of two revolutions per second. You get an output speed of two revolutions per second from an input of four revolutions per second, with a speed reduction of 1/2.

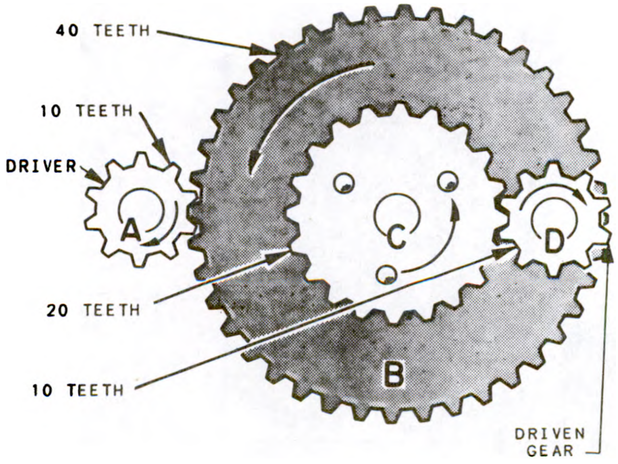


Figure 3-8.—Simple reduction gears.

Almost any increase or decrease in speed can be obtained by choosing the correct gears for the job.

Magnifying Force

Gear trains can be used to increase mechanical advantage. The rule is, whenever you reduce speed with a gear train, you increase the effect of the force applied. The theory of this principle will not be discussed here. For further information on gears and gear trains as well as the theories of how they work, see the Navy Training Manual, *Basic Machines*, NAVEDTRA 10624-A1.

LEVERS AND LINKAGES

One of the simplest and most familiar types of machines is the lever. Levers are used to overcome big resistances with relatively small effort. The principle of leverage is used extensively throughout ordnance equipment.

The three basic components which comprise all levers are the FULCRUM (F), a force or EFFORT (E), and a RESISTANCE (R). Look at the lever in figure 3-9. You see the pivot point F (fulcrum); the effort (E), which you apply at a distance (A) from the fulcrum; and a resistance (R), which acts at a distance (a) from the fulcrum. Distances (A) and (a) are the lever arms.

The application of leverage in ordnance equipment uses mechanical linkages to transmit and

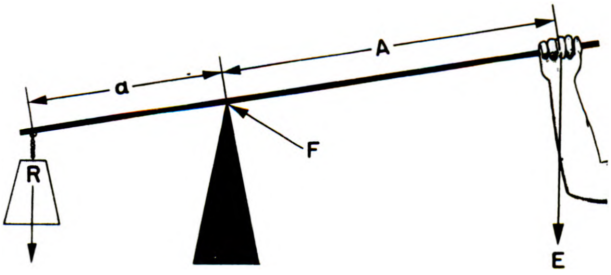
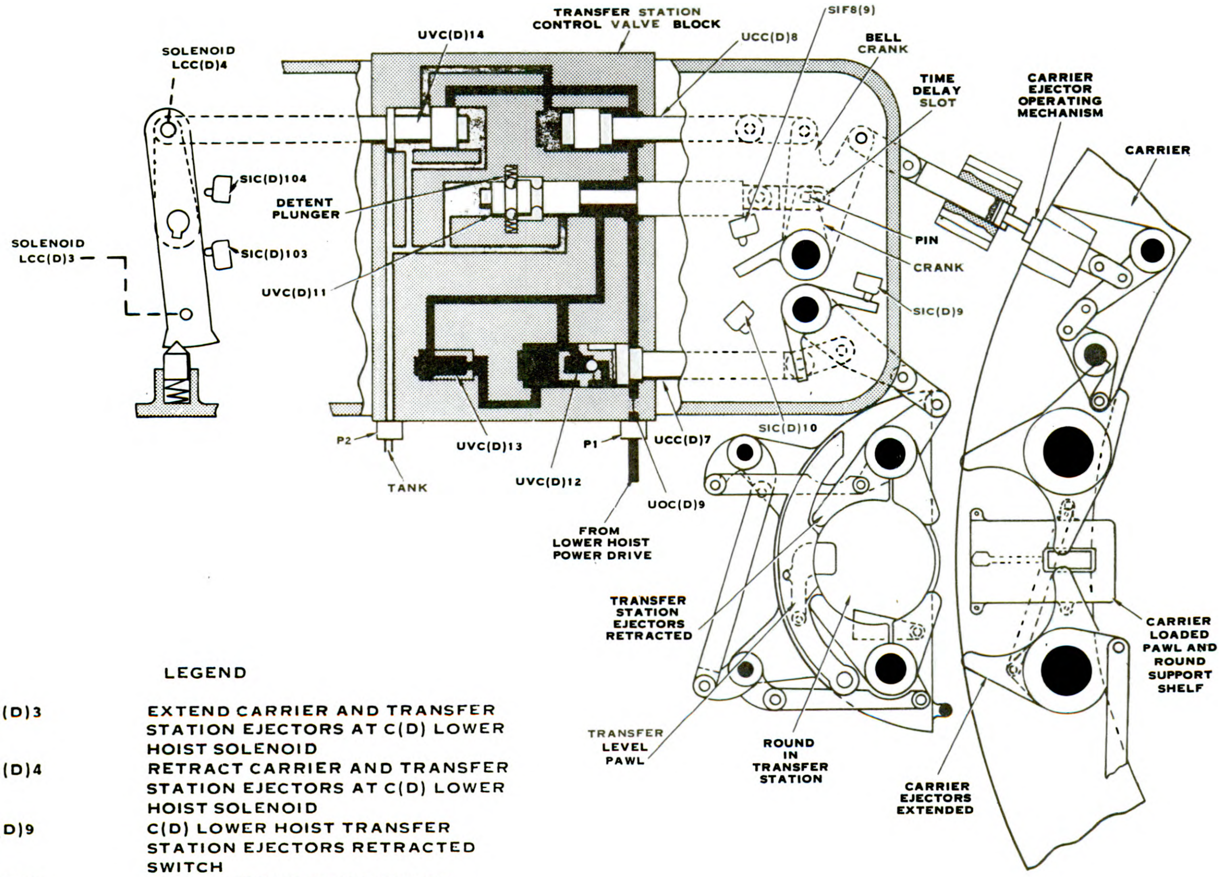


Figure 3-9.—A simple lever.

increase force. Figure 3-10 shows the mechanical linkages in a 5″/54 Mk 42 Mod 10 carrier ejector assembly. The linkages act together to eject a complete round of ammunition from the transfer station to the carrier tube. The carrier tube must be completely open before the round is ejected into it. Therefore, a time delay slot is incorporated to allow the linkages to move, opening the carrier before the transfer station ejectors actuate. For further information on the fundamentals of levers and linkages, see the Navy Training Manual, *Basic Machines*, NAVEDTRA 10624-A1.

HYDRAULIC MACHINES

Hydraulic machines are used throughout ordnance equipment. They provide smooth and


TRANSFER STATION CONTROL VALVE BLOCK
UVC(D)14
SOLENOID LCC(D)4
UCC(D)8
SIF8(9)
BELL CRANK
TIME DELAY SLOT
CARRIER EJECTOR OPERATING MECHANISM
CARRIER
SIC(D)104
DETENT PLUNGER
SOLENOID LCC(D)3
SIC(D)103
UVC(D)11
PIN
CRANK
SIC(D)9
SIC(D)10
P2
UVC(D)13
P1
UCC(D)7
TANK
UVC(D)12
UOC(D)9
FROM LOWER HOIST POWER DRIVE
TRANSFER STATION EJECTORS RETRACTED
CARRIER LOADED PAWL AND ROUND SUPPORT SHELF
TRANSFER LEVEL PAWL
ROUND IN TRANSFER STATION
CARRIER EJECTORS EXTENDED

LEGEND

LCC(D)3	EXTEND CARRIER AND TRANSFER STATION EJECTORS AT C(D) LOWER HOIST SOLENOID
LCC(D)4	RETRACT CARRIER AND TRANSFER STATION EJECTORS AT C(D) LOWER HOIST SOLENOID
SIC(D)9	C(D) LOWER HOIST TRANSFER STATION EJECTORS RETRACTED SWITCH
SIC(D)10	C(D) LOWER HOIST TRANSFER STATION EJECTORS EXTENDED SWITCH
SIC(D)103	C(D) HOIST TRANSFER STATION EJECTORS EXTEND SOLENOID ENERGIZED SWITCH
SIC(D)104	C(D) HOIST TRANSFER STATION EJECTORS RETRACT SOLENOID ENERGIZED SWITCH
SIF8(9)	CARRIER EJECTORS AT C(D) LOWER HOIST RETRACTED SWITCH
UCC(D)7	TRANSFER STATION EJECTOR OPERATING PISTON
UCC(D)8	CARRIER TUBE EJECTOR OPERATING PISTON
UOC(D)9	ORIFICE
UVC(D)11	CARRIER EJECTOR CONTROL VALVE
UVC(D)12	CHECK VALVE
UVC(D)13	METERING VALVE
UVC(D)14	EJECTOR CONTROL VALVE

■ = SERVO PRESSURE

▨ = TANK

Figure 3-10.—The 5″/54 carrier ejector mechanism.

accurate train and elevation movement for gun mounts and missile launchers, as well as operate the loading systems. To appreciate the usefulness of hydraulics, we need to understand some basic characteristics and definitions. In the practical sense, hydraulics is concerned with the uses of a fluid filled system in transmitting applied forces and producing (or controlling) mechanical motion.

FLUID CHARACTERISTICS

Let's deal first with transmitting of applied force. The two qualities of fluids that make them useful as a means to transmit force are as follows:

1. They take the shape of their container
2. They are not compressible

Therefore, pressure applied to a fluid in a closed container will be felt equally against the entire inside surface of the container. The force is transmitted equally in all directions as shown in figure 3-11. This is true regardless of the shape of the container. This means it is not necessary for the tube connecting the two pistons to be as large as the pistons throughout. A connection of any size, shape, or length will do, as illustrated in figure 3-12. The size of the line, however, will determine the volume of fluid flow, which in turn, effects operating speed.

In figures 3-11 and 3-12, the systems contain pistons with the same area. This makes the output force equal to the input force. Remember what we said earlier: the force applied is transmitted to all surfaces in the container equally.

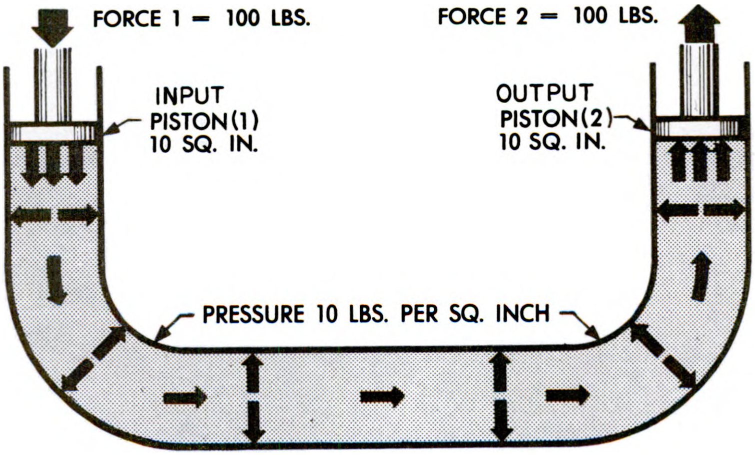

FORCE 1 = 100 LBS.
FORCE 2 = 100 LBS.
INPUT PISTON(1) 10 SQ. IN.
OUTPUT PISTON(2) 10 SQ. IN.
PRESSURE 10 LBS. PER SQ. INCH

Figure 3-11.—Force transmitted through fluid.

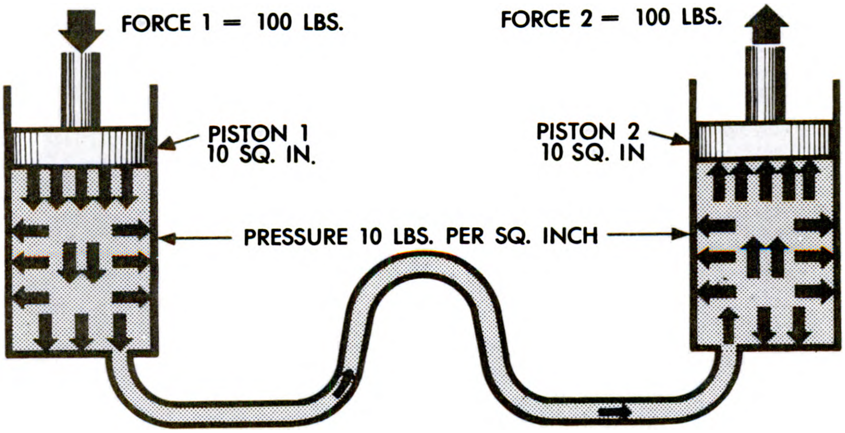


Figure 3-12.—Transmitting force through a small pipe.

Now consider figure 3-13, the input piston is much smaller than the output piston. Assume the area of the input piston is 2 square inches. With a force of 20 pounds applied to it, a pressure of 10 pounds per square inch will be felt throughout the container including the output piston. The upward force on the output piston is therefore 10 pounds for each of its 20 square inches or 200 pounds. We have effectively multiplied the applied force.

The system works the same in reverse. Consider piston (2) as the input piston and piston (1) as the output. Then the output force will always be one-tenth the input force.

You should now have a basic understanding of hydraulic principles. More information on hydraulic principles and theory can be found in the Navy Training Manual, *Fluid Power*, NAVEDTRA 12964.

SYSTEM COMPONENTS

We will now discuss some of the hydraulic components that are used in ordnance equipment. We will cover common system components: pumps, actuator pistons, and hydraulic power drives.

Every hydraulic system has the same basic requirements. It must have a tank to store an adequate supply of fluid, a pump, and a device for removing impurities from the fluid. Most systems also have a mechanism for regulating the system output pressure and a flask for storing fluid under pressure.

Reservoirs

The reservoir (fig. 3-14) is a basic component of any hydraulic system. In most systems, the reservoir is a separate component. It may also be used as a housing with the hydraulic pump inside submerged in fluid. Although its primary function is to provide storage space for the system's fluid, it may also perform several other functions. Reservoirs may be used to dissipate heat, separate air from the system, and remove contamination.

Reservoirs dissipate heat by radiation from the external walls. Some are constructed with external radiating devices such as cooling coils or fins. The separation of air from the system is accomplished by the design of the reservoir. Baffles are used to slow the fluid as it returns to the reservoir. Air bubbles have a greater chance of escaping to the surface when the fluid is moving at a slow velocity. The tank is fitted with a device that

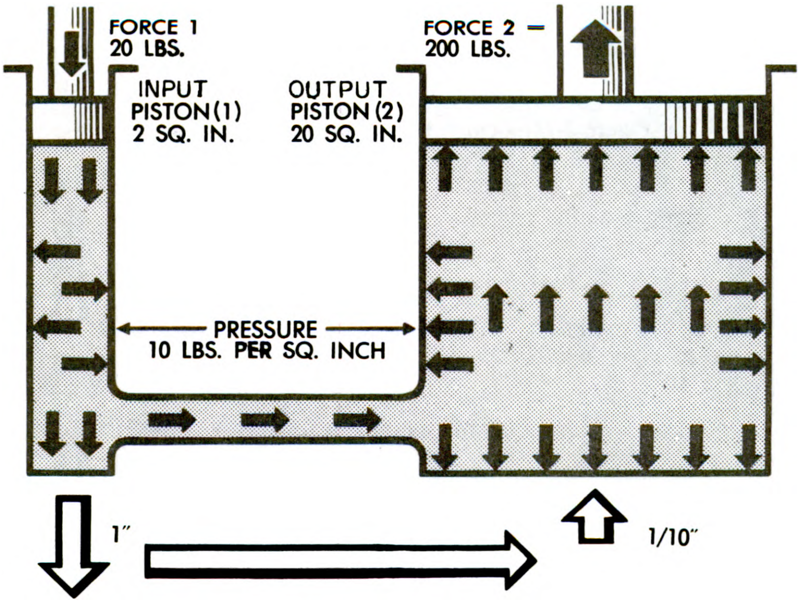


Figure 3-13.—Multiplication of forces.

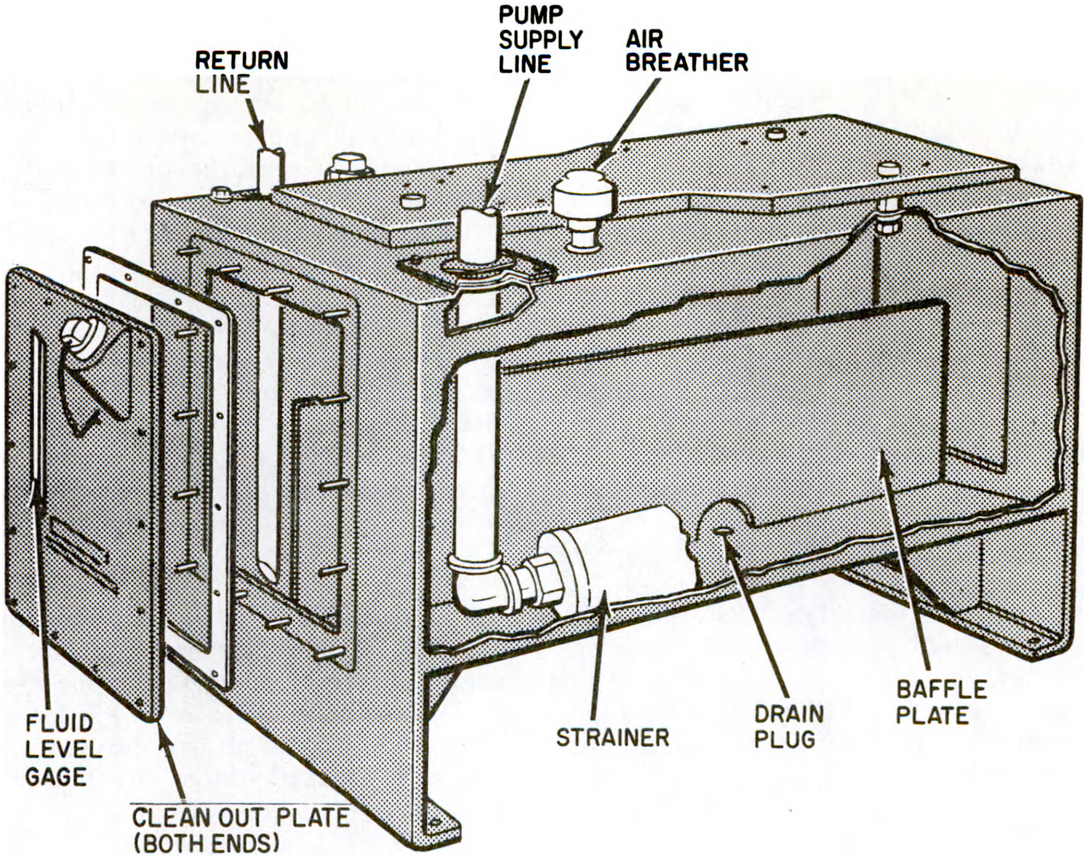


Figure 3-14.—A fluid reservoir.

allows the air bubbles to escape, while not permitting contamination to enter. The separation of contamination from the fluid requires some form of filter or strainer.

Filtering Devices

Most malfunctions in a hydraulic system can be traced to some type of contamination in the fluid. Foreign matter in the system can cause excessive wear, increased power loss, and clogged valves, which increase maintenance costs. For this reason, every effort must be made to prevent contaminants from entering the system. Contaminants that do make their way into the system must be removed before they can cause damage. Filtration devices perform this function.

The filtering devices used in hydraulic systems are most commonly referred to as strainers and filters. Since they share a common function, the terms *strainer* and *filter* are often used interchangeably. As a general rule, devices used to remove large particles are called strainers, and those used to remove small particles are called filters.

A strainer will most often be found on the end of the pipe used to supply fluid to a pump from the reservoir. There it can remove any large particles that could clog or damage the pump. Filters can be placed anywhere in the system, but are usually located between the pump and the pressure control device. Pumps do not normally have small orifices that could easily clog. Pressure control devices, however, use very small passages and pistons that must be kept clear for proper operation.

Filters are classified as full flow or proportional flow. In the full-flow type filter, all the fluid passes through the filtering element. In the proportional-flow type, only a portion of the fluid is passed through the filter. Because of the complex nature of ordnance equipment, most systems use the full-flow type of filter. Figure 3-15 illustrates a full-flow filter device (view A) and a common micronic filter element (view B). This type of element is designed to prevent the passage of 99 percent of solids greater than 10 microns in size. The element is usually made of disposable paper and is required to be replaced at regular intervals. Notice that the filter device is equipped with a by-pass valve. Should the filter become clogged, the by-pass valve opens, allowing unfiltered fluid to enter the system. This triggers an indication to the system operator that the filter is clogged. The system should be secured and the filter replaced immediately. The system does not secure itself under these conditions since the filters could clog in the heat of battle.

Pressure Regulators

The control and unloading valve shown in figure 3-16 are used to regulate the operating pressure in an accumulator power drive system. The operating range of the fluid pressure for the functional description that follows is assumed to be 950 psi to 1050 psi.

The control valve and its piston maintain the operating range of the system's fluid pressure by controlling the position of the unloading valve. The unloading valve (also called a by-pass valve) is a three-way, plunger-type directional valve. Its function is to port the pump output to the accumulator during a charge cycle, or to tank (back to the reservoir) during an unloading cycle.

During an accumulator charging cycle (fig. 3-16, part A), the spring holds the control valve in the down position. A drilled hole through the lower land of the control valve ports system pressure (PA) from the accumulator to the chamber between the control valve and its piston. The piston has PA applied to both ends and, therefore, does not affect operation of the control valve during this portion of the cycle. However, PA is only applied to the lower end of the control valve. The position of the control valve is determined by the amount of pressure in the accumulator system. As the pressure increases, the valve moves upward against spring pressure.

During the charging cycle, PA is also ported from the upper chamber of the control valve to the spring-loaded (large area) side of the

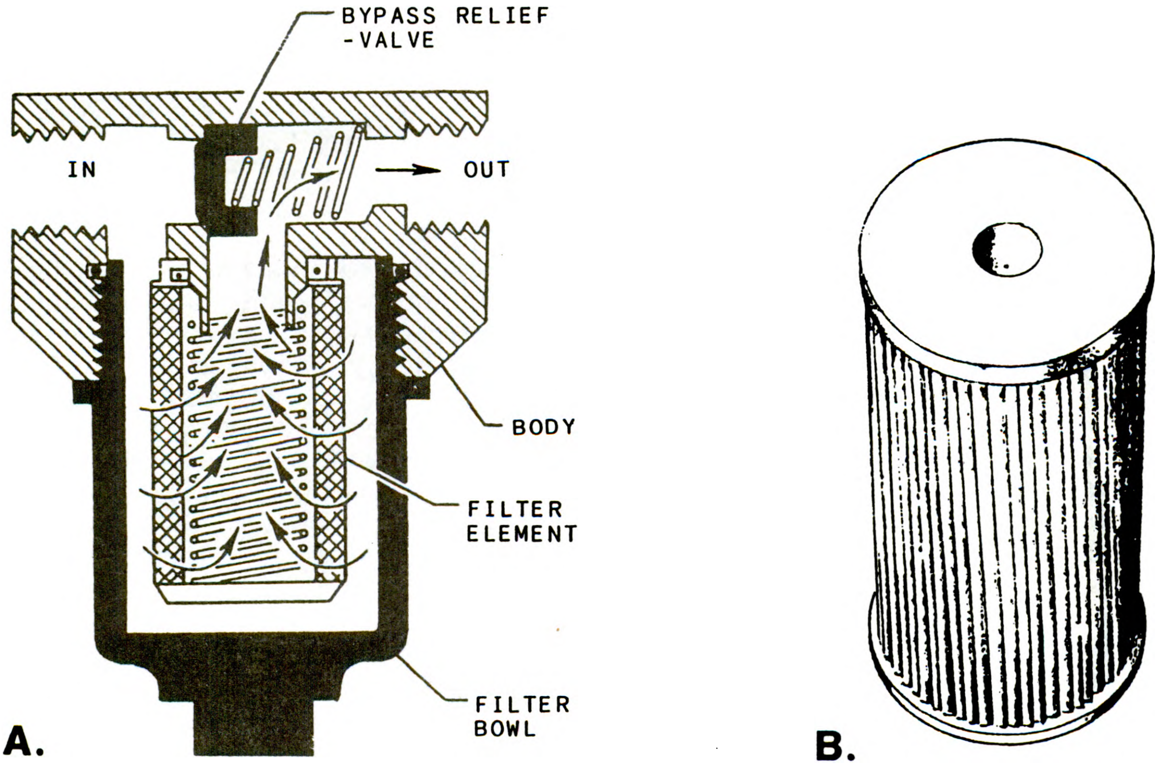


Figure 3-15.—A. A full-flow filtering device; B. A micronic filter element.

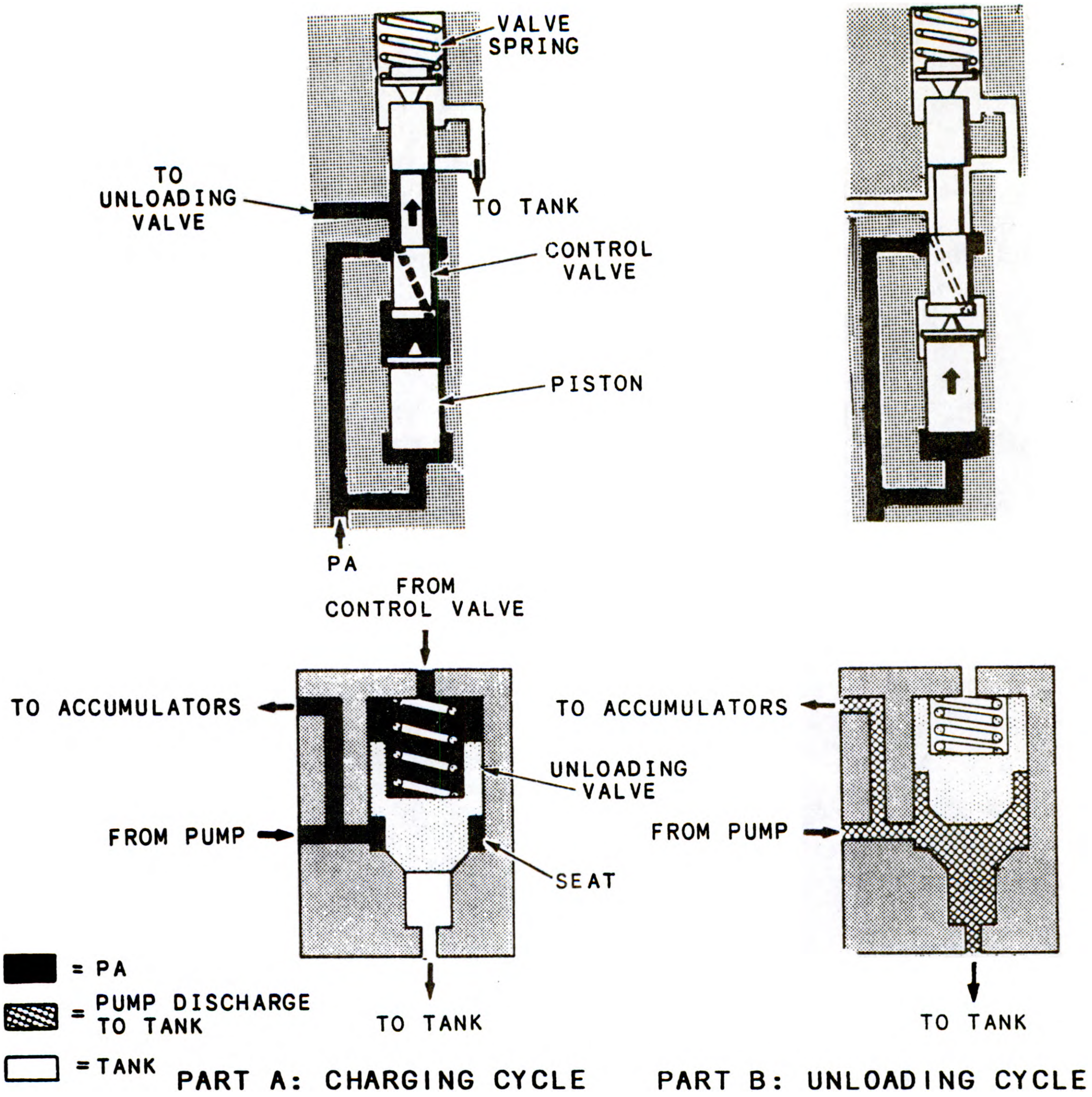


Figure 3-16.—Control and unloading valves.

unloading valve. Pump output is also applied to the lower area around the unloading valve's seat (small area). The combination of spring pressure and PA on the large area keeps the unloading valve on its seat. In this position, fluid discharged by the pump is ported to the accumulator.

As fluid pressure in the accumulator increases, it forces the control valve upward against its spring pressure. When the pressure reaches 1050 psi, the lower land of the control valve blocks PA and the upper land uncovers the tank line (fig. 3-16, part B). This vents the pressure from the chamber between the control valve and its piston and from the large area side of the unloading valve.

With no pressure in the chamber between the control valve and its piston, the piston moves upward into contact with the valve. Because the piston is larger in diameter (more working area for the fluid pressure) than the control valve, the control valve moves further up against spring pressure.

When the pressure is vented from the large area side of the unloading valve, the pressure in the pump output line, acting on the area around the unloading valve's seat, overcomes spring pressure, and shifts the valve upward. This causes pump output to be discharged to tank.

During the unload cycle, PA, acting on the bottom of the control valve piston, holds the control valve in the up position against spring pressure. As the pressure in the accumulator system decreases, spring pressure overcomes fluid pressure, moving both the control valve and its piston downward. When system pressure decreases to 950 psi, the upper land of the control valve covers the tank line, and the lower land opens the PA line. PA enters the chamber between the control valve and its piston. PA is also ported to the large area side of the unloading valve, forcing it on its seat and beginning another charging cycle.

Pressure Accumulator

Accumulator power drive systems are the most common hydraulic power drives used in ordnance equipment. Instead of having the output flow of the system's pump being put directly to use operating a mechanism, it is pumped into an accumulator flask. The prime function of the accumulator is to store a volume of fluid under pressure. As the system demands fluid, it is supplied from the flask. The pressure regulator we just described monitors the pressure in the flask, keeping it within prescribed limits. Systems that require a high volume of fluid under pressure will be equipped with several flasks. The upper gun loading system of a 5″/54 Mk 42 gun mount, for instance, has six accumulator flasks.

Figure 3-17 illustrates the most common type of accumulator —the gas-operated, bladder-type flask. This accumulator flask uses a nitrogen-filled bladder inside a steel cylinder. The cylinder has a poppet valve to keep the bladder from being pushed into the output line by its nitrogen pressure when the system is not energized. The bladder, filled with nitrogen to a certain pressure, is compressed by the fluid as the cylinder fills. When the upper level pressure is reached, fluid flow from the pump to the accumulator is stopped. The bladder pressure then continues to cause fluid flow, maintaining system pressure. Without the accumulator flasks, the system's pump could easily fall behind system requirements during times of peak demand.

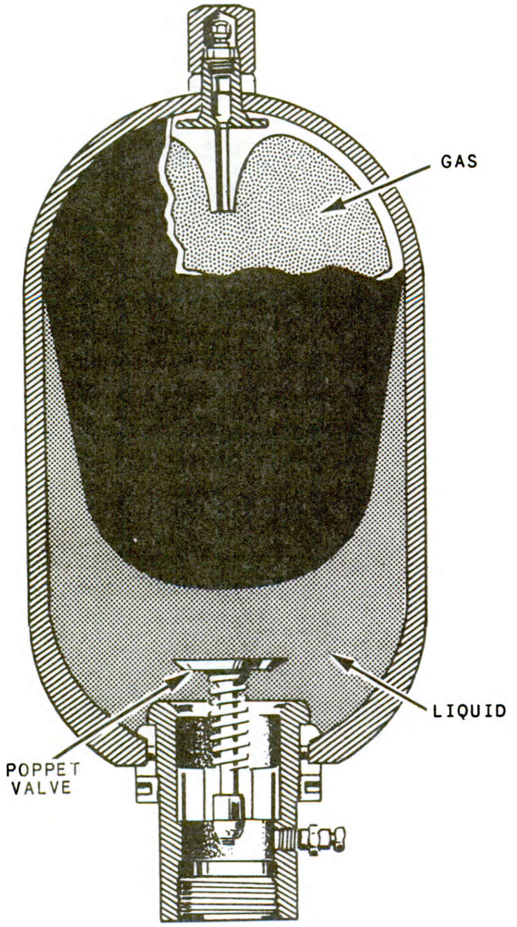


Figure 3-17.—A gas-operated, bladder-type accumulator.

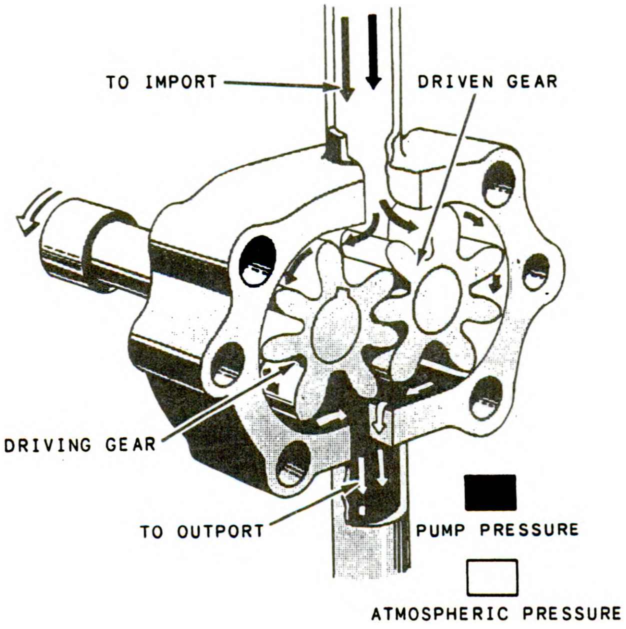


Figure 3-18.—A rotary gear pump.

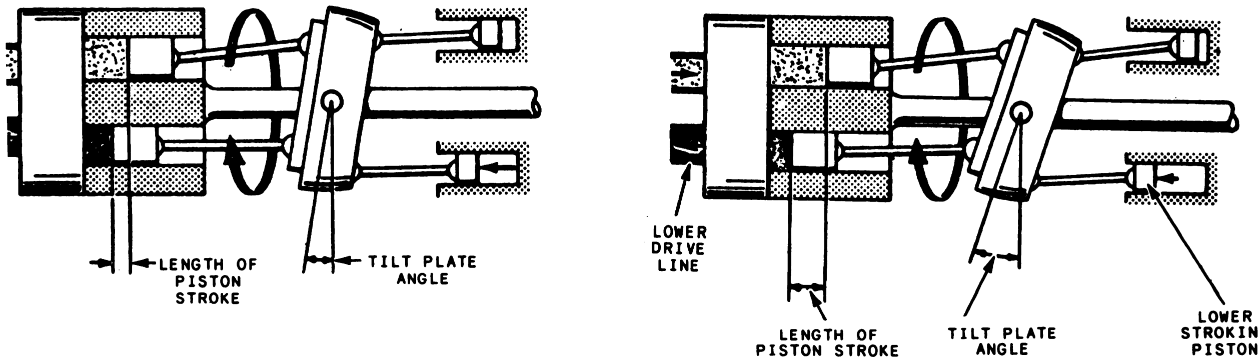
Pumps and Power Drives

The purpose of a hydraulic pump is to supply a flow of fluid to a hydraulic system. The pump does not produce pressure. The pressure is developed in the system due to the system's resistance to fluid flow. Pumps can be of several different types, but the most common are the rotary gear pump and the axial piston pump.

The rotary gear pump (fig. 3-18) operates by trapping fluid at the inlet (suction) port and forcing it through the discharge port to the system. The gear pump is used throughout ordnance systems to supply fluid flow at a variety of pressures. They are most efficient, however, at pressures around 500 psi. There are several configurations and modifications of the gear pump. These will not be discussed in this text.

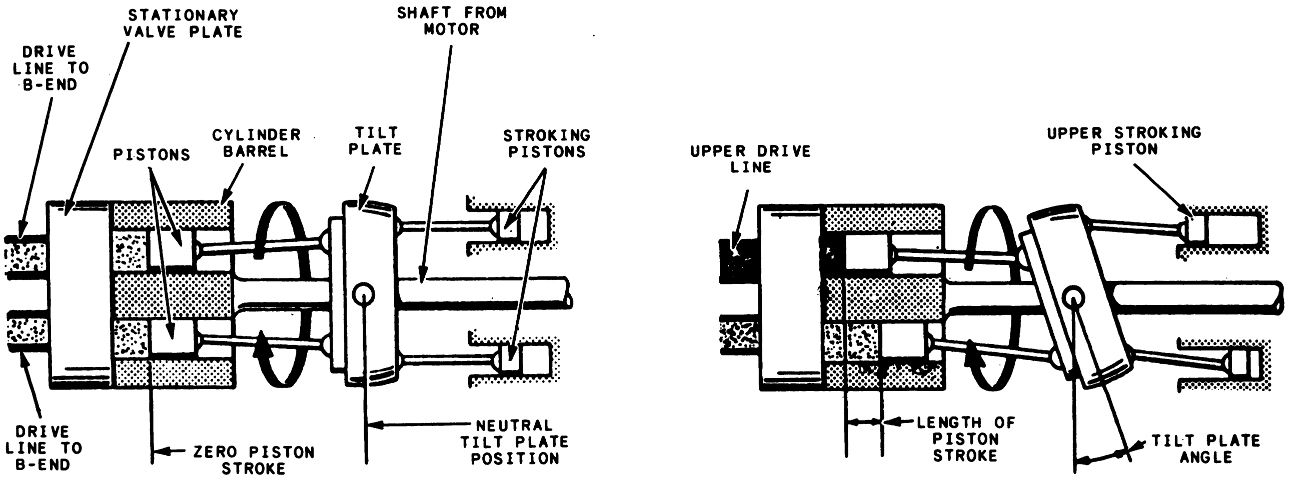
The axial piston pump is used in most power drives that require either a variable output or a high volume output. First, let's describe the principle of operation, then we can show how they are used.

Figure 3-19 illustrates how the output of an axial piston pump is varied. The pump uses pistons attached to a movable tilt-plate. The pistons and cylinder barrel rotate together, driven by an electric motor, between the tilt-plate and the valve-plate. The tilt-plate is moved either left or right by stroking pistons. The larger the tilt angle, the longer the piston stroke, the larger the quantity of pump output. The direction of flow is reversed by reversing the direction of tilt. When the piston stroke is on zero stroke, there is no pump output, even though the pump is still rotating.



A. TILT PLATE POSITIONED FOR SHORT STROKE.

B. TILT PLATE POSITIONED FOR LONG STROKE.



C. TILT PLATE AT NEUTRAL POSITION.

D. TILT PLATE AT REVERSE ANGLE.

Figure 3-19.—Operation of the axial piston pump.

This configuration of the axial piston pump is used primarily for the train and elevation power drives, magazine ready service rings, and loaders on gun mounts and missile launchers. The pump output is used to drive a hydraulic motor. The only difference between the pump (A-end) and the hydraulic motor (B-end) is that the tilt plate is set at a permanent angle. These combination A-end pumps and B-end motors are referred to as CAB units. Figure 3-20 illustrates a CAB unit setup. The pump output is transmitted to the motor, which operates just the reverse of the pump. The pump takes a mechanical input and turns it into a variable bidirectional hydraulic output. The motor takes a variable hydraulic input and converts it to a variable bidirectional mechanical output.

Another common configuration uses the same pump but with a fixed angle tilt plate. The pump has a constant output that is supplied to an accumulator system with a pressure regulator. This type is used to power most gun mount and missile launcher loading systems.

HYDRAULIC MECHANISMS

Now that we have seen the basic components of a hydraulic system, let's take a look at a hydraulic mechanism. Up to now, we have pumped the hydraulic fluid from the reservoir, through the filter, and have it regulated to the desired pressure. Now, let's have it do some work.

Glance back to figure 3-10. This is the illustration of the 5"/54 carrier ejector mechanism we used as an example of a mechanical ordnance device. The linkages in the ejector are operated by hydraulic pistons. The pistons extend and retract to operate the ejector. The fluid that moves the pistons is controlled electrically by solenoids. Figure 3-21 shows the inside of a solenoid housing and valve block.

Notice that there are two solenoids attached to the same linkage at opposite ends. The linkage has a pivot point in the middle. The pivot is actually a shaft that extends through the solenoid housing into a hydraulic valve block. The linkage is keyed to the shaft so that when one of the solenoids is energized and moves the lever, the shaft will rotate. Inside the valve block (fig. 3-21), the shaft is attached to a valve. As the shaft is rotated, it positions the valve. One position allows fluid to be ported to one side of the piston, extending it. The other position ports fluid to the other side of the piston, retracting it. When fluid is ported to either side, the other side is

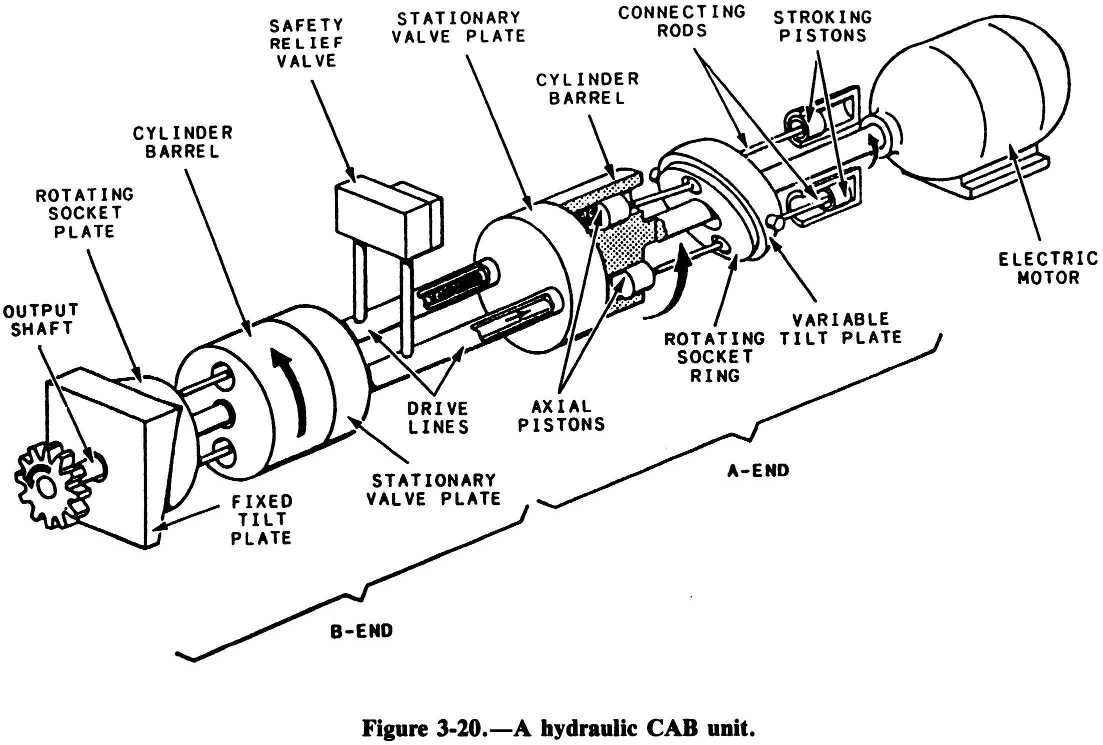


Figure 3-20.—A hydraulic CAB unit.

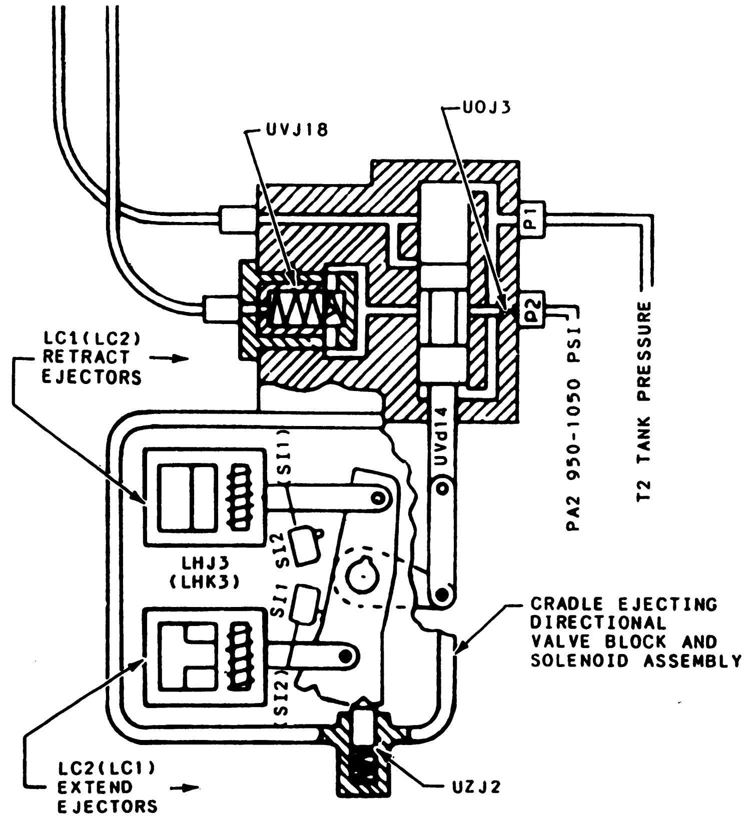


Figure 3-21.—Solenoid housing and valve block.

opened to allow the trapped fluid to return to tank.

This concludes our coverage of hydraulic systems. You should now have a basic understanding of the hydraulic mechanisms used in ordnance equipment. For more information, see the Navy Training Manual, *Fluid Power*, NAVEDTRA 12964, or system publications.

AIR SYSTEMS

Most, if not all, ordnance systems use compressed air in one way or another. Though the compressed air supply system is not considered part of your ordnance equipment, it is a critical support element. In many cases, you may find that the lack of compressed air can stop the most carefully planned exercise. Many Gunners have learned the hard way—you need to check the availability of compressed air the day before an important exercise. It is extremely important that you know where your air comes from and who controls it.

The supply system is operated and maintained by the ship's engineers. Air systems are classified by their operating pressures. In the ordnance world we are concerned with high-pressure (HP) and low-pressure (LP) air. We will now briefly discuss these two systems as well as the concept of vital air.

HP AIR

HP air plants and systems are generally designed to provide compressed air at a nominal operating pressure of 3000 psi or 5000 psi. They are installed when one of the ship's services requires a pressure in excess of 1000 psi. They are also used when a ship's function requires a flow rate that cannot be readily supported by either a low-pressure or medium-pressure plant. HP compressed air plants support high flow demand systems by the addition of HP air storage flasks in the system. Once an adequate quantity of compressed air is stored in these flasks, the high flow rates and pressure demands can be supported by way of pressure reducing stations.

A good example of this is the air supply to a gun mount gas ejection system. The gas ejection system, as shown in figure 3-22, uses compressed air to evacuate gases and unburned solids from the bore after firing. The compressed air is pumped from the engineering space to a flask in the vicinity of the gun mount. The air is then routed through a reducer, where it is regulated to system pressure, then up to the gun where it is used. The same air is also used, without passing through the reducer, to recharge the gun's counterrecoil system after maintenance.

Figure 3-23 illustrates how HP air is used throughout ordnance equipment. It is used to fire torpedoes from their tubes, to operate the dud-jettison systems on guided missile launchers, and to operate equipment air drive motors, as well as many other systems.

LP AIR

Low-pressure (LP) air systems are designed for nominal operating pressure of 150 psi and below. LP air has hundreds of uses throughout the ship, unlike HP air which is used primarily by weapon systems. This has necessitated the development of the vital/nonvital air main concept.

Figure 3-24 illustrates a typical LP air system that employs the vital/nonvital air main concept. The system uses a priority valve to cut out certain sections of the LP air main when system pressure drops below a predetermined level. As you can see, the vital system feeds electronic dry air to the weapon system radars and control air to the engineering plant.

Electronic dry air is the primary use of LP air in ordnance equipment. Radar systems use

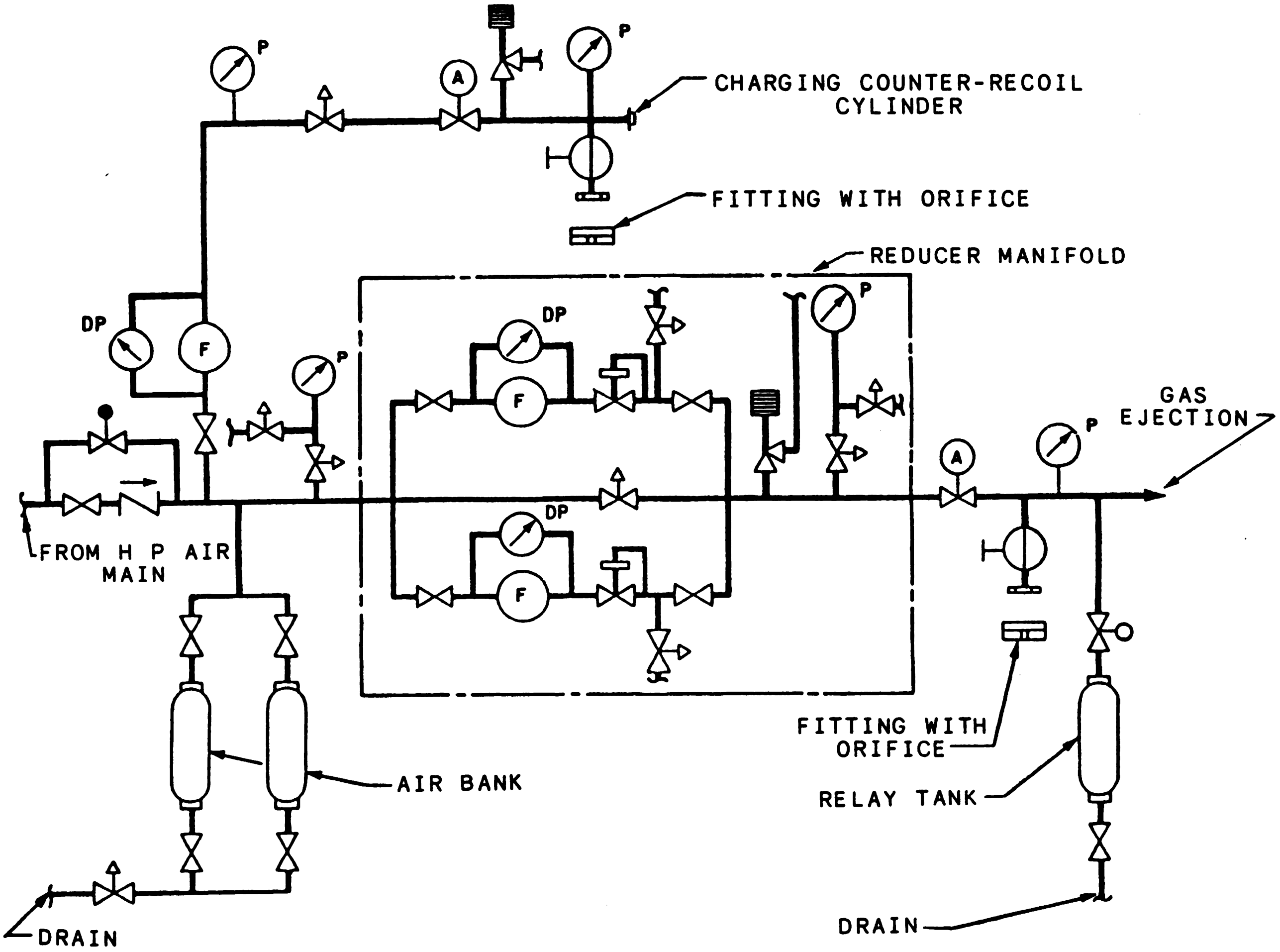


Figure 3-22.—HP air for gas ejection and counterrecoil.

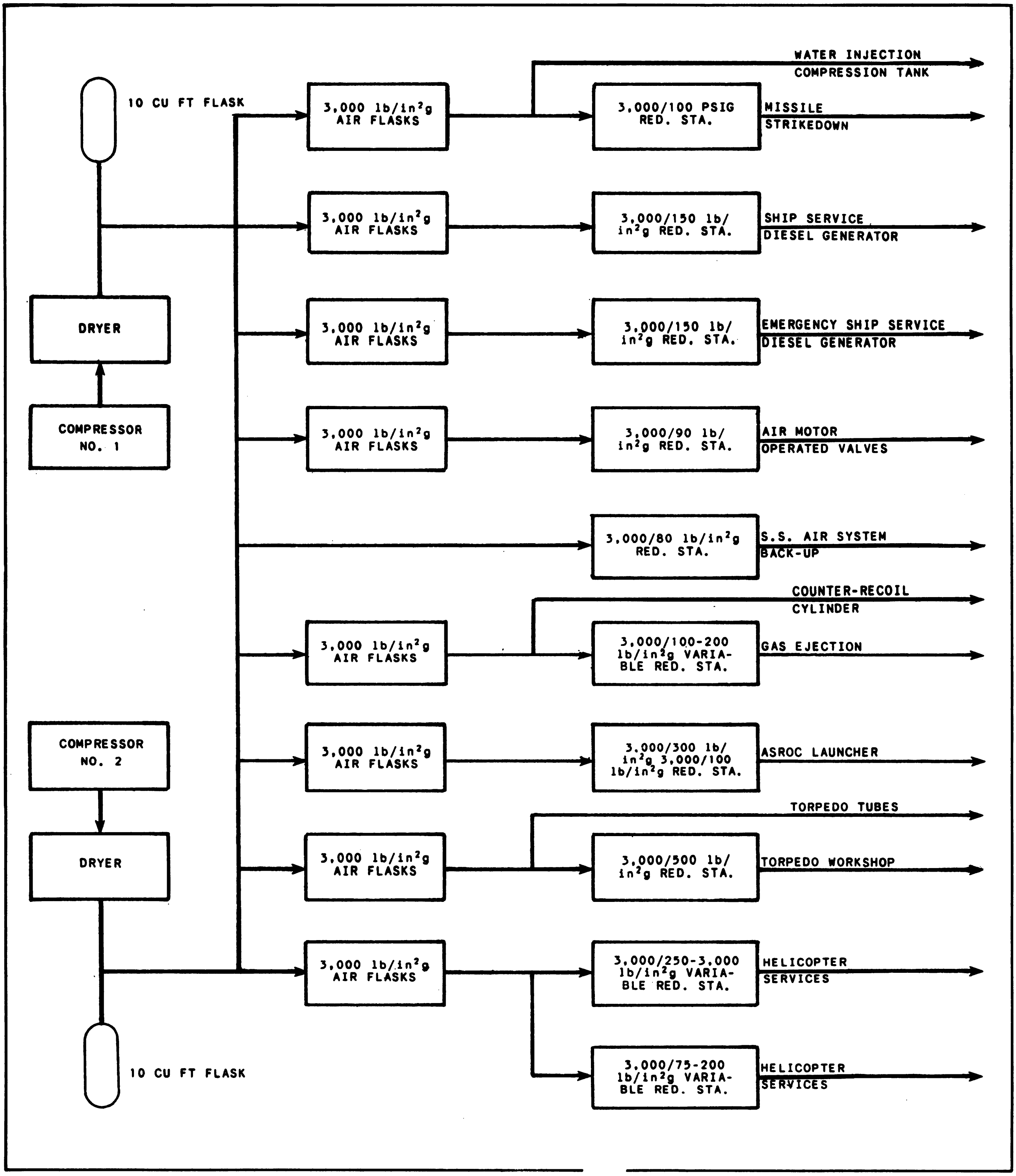


Figure 3-23.—Typical HP air functional diagram.

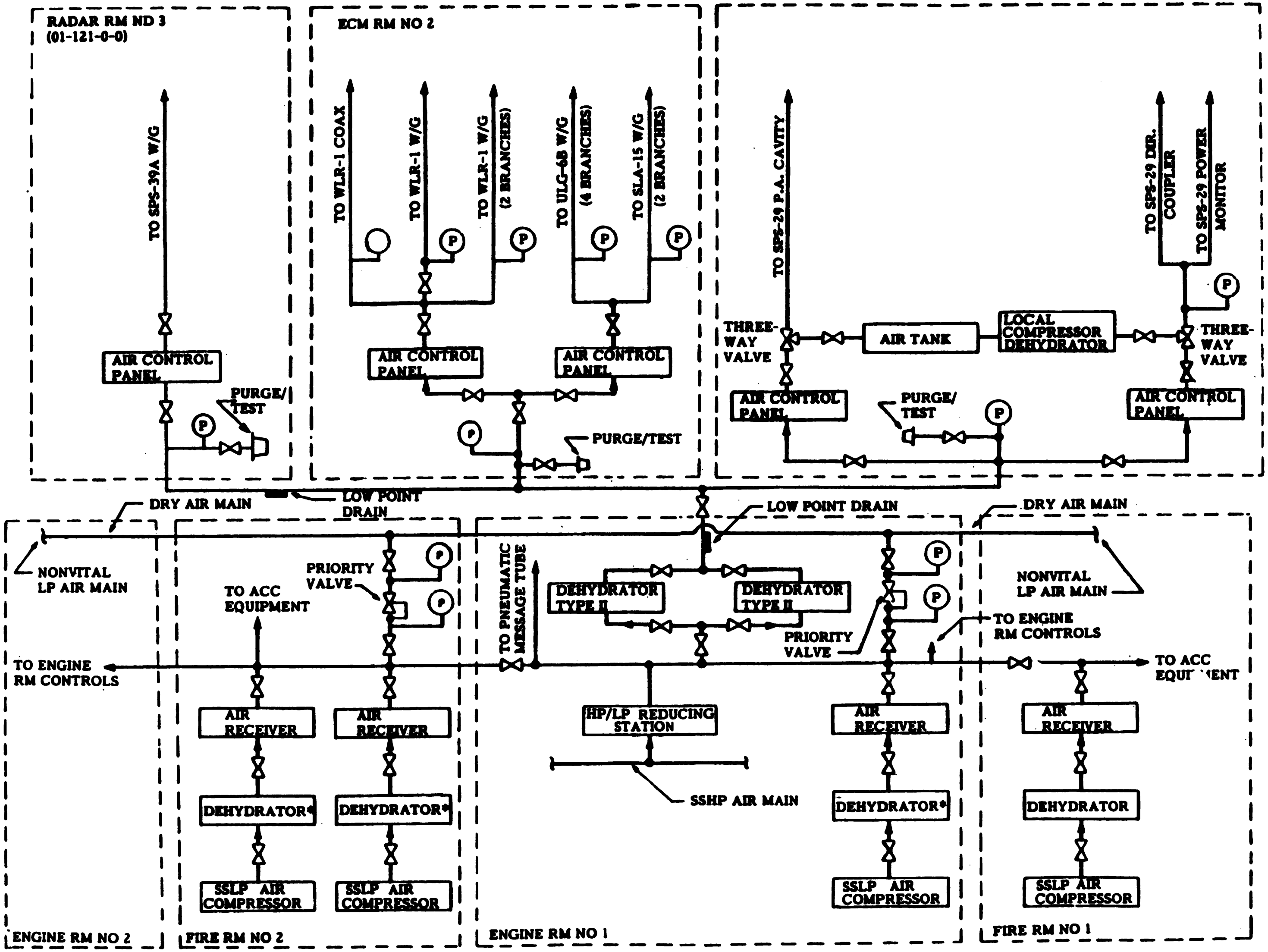


Figure 3-24.—LP air system using the vital/nonvital air main concept.

waveguides to convey the electronic pulse from the transmitter to the antenna on the mast. The antenna emits the signal and collects the echo. The echo is then sent back down through the waveguide to the receiver. Since the waveguide is used to pass high power radio emissions, it must be kept clean and dry. This is accomplished by continuously pumping electronic dry air through the waveguide. Dry air is made by pumping LP air through a series of air dehydrators. Other uses include powering various handling equipment, such as air hoists. The intent of this small section on compressed air systems has been to make you aware of them and of the impact their operating status can have on your equipment. As an officer in the weapons department, you will have to find out exactly how your equipment depends on compressed air. Coordination between your division and the engineers, concerning compressed air and electrical power, which is covered next, is most essential.

To learn more about dehydrators and other air system specifics, refer to *Naval Ship's Technical Manual*, S9086-SY-STM-010 Chapter 551, "Compressed Air Plants and Systems", and system publications.

SHIP'S POWER AND DISTRIBUTION

As with compressed air, the electric power you need to run your equipment is generated and controlled by the ship's engineers. Ship's power is referred to as either 60 or 400 Hertz. All ship's electrical power begins as the 440 volt, 60 cycle, three-phase output of the ship's generators. This output, as shown in figure 3-25, is directed through the ship's main switchboards to the various sections of the ship. Transformers are

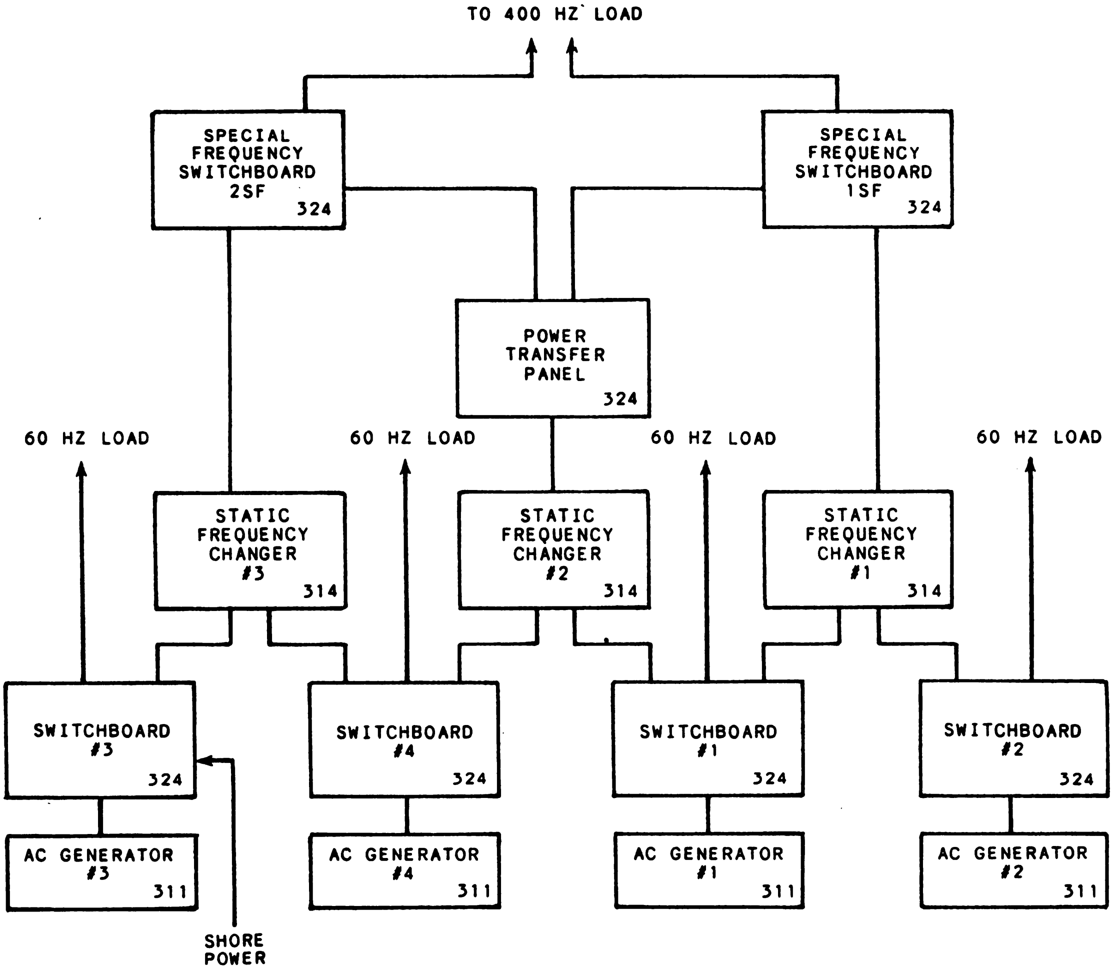


Figure 3-25.—Shipboard power distribution on an FFG-7 class ship.

used to regulate some of the output to 115 volt, 60-Hertz ac for lighting and other common uses. Other circuits, such as the one in figure 3-26, convert some of the output to 400 Hertz for use in radar and communication equipment.

All weapon systems require electrical power to operate. However, some are much more sensitive to power fluctuations and power losses than others. A power loss could severely damage the sophisticated electronics in a radar unit; a missile launcher drive motor would just shut down. Power fluctuations can be even more damaging to electronics than a total loss of power.

Most essential equipments have more than one source of electrical power. Both the primary and secondary sources are made available to the equipment through a large switch, called an automatic buss transfer (ABT). The ABT powers the equipment from the primary source as long as it is available. Should the primary source be interrupted for any reason, it switches to the secondary source automatically.

It is beyond the scope of this text to explain the details of electric power generation and distribution. Our intent is to give you the fundamental knowledge of its existence and impact on your equipment. For further information about power generation/distribution, refer to the Navy Electricity and Electronics Training Series (NEETS), Module 5, *Introduction to Generators and Motors*, NAVEDTRA 172-05-00-79; *Electrician's Mate* 3 & 2, NAVEDTRA 10546-F, and ship's drawings.

ELECTRONICS

The scope of electronics used in ordnance equipment is broad to the point of including nearly every system and subsystem. Electronics, by definition, is "the science dealing with the

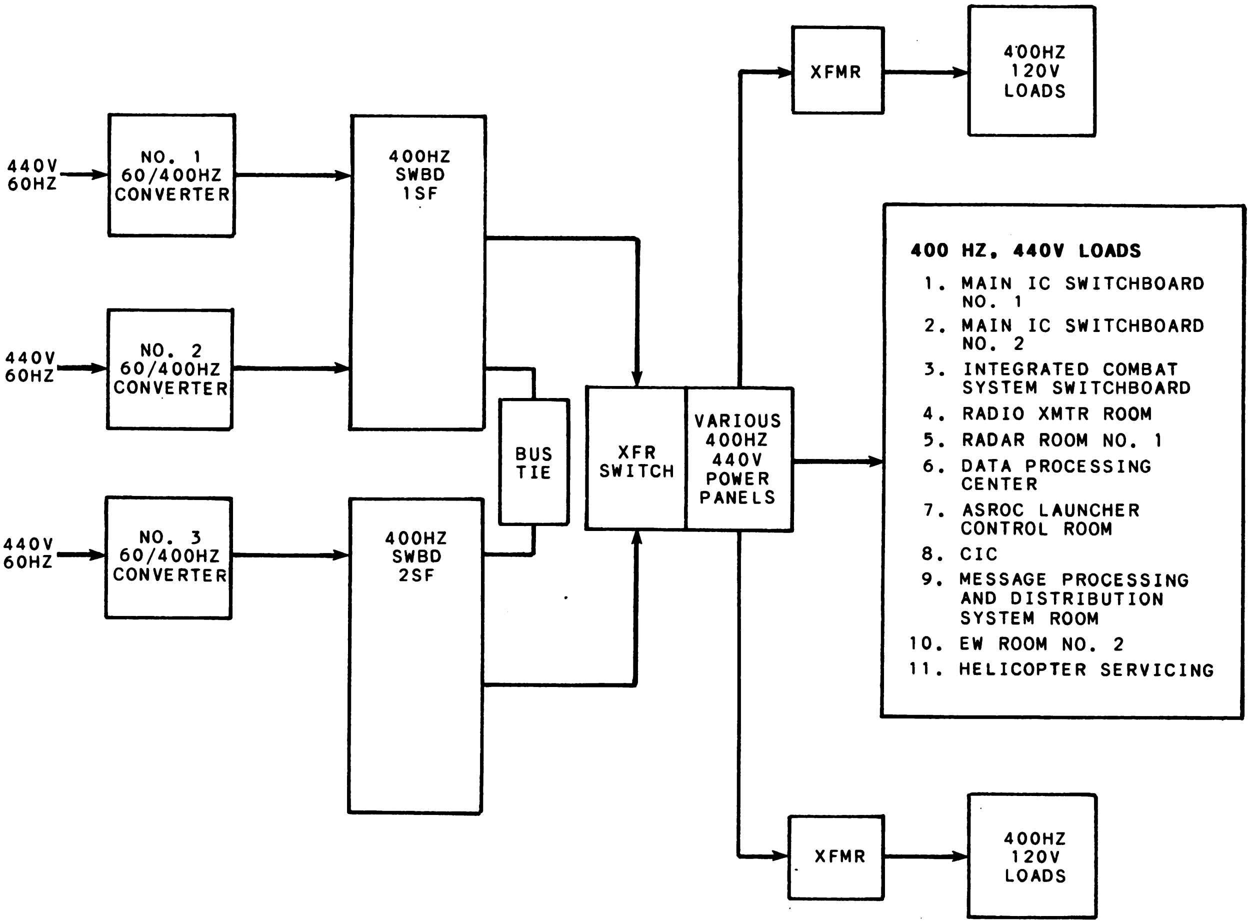


Figure 3-26.—400-HZ power on a DD-963 class ship.

development and application of devices and systems involving the flow of electrons in a vacuum, in gaseous media, and in semiconductors." The obvious ordnance system applications of electronic devices include radar, sonar, EW gear, fire control, and communication equipment. Other less apparent applications, include the systems used to control the movement and complex loading systems of missile launchers and gun mounts.

None of these systems lend themselves to an explanation that would be both meaningful and concise. With that, and with the general nature of this text in mind, we will not attempt to cover the detailed function of any electronic equipment. In later chapters that describe specific systems, we will point out the use of electronics as they apply. For more detailed information concerning a specific system or electronic device, you should refer to one or more of the following sources:

1. Rate training manuals
2. The Navy Electricity and Electronics Training Series (NEETS)
3. System manuals

SUMMARY

Ordnance technology has evolved to the point of becoming an exact science. System technicians who operate and maintain the equipment require months of training to be effective. Our goal has not been to make you a technician, but to give you a basic knowledge to build on. In later chapters you will see how each of these basic mechanisms are used. Many devices are common to several different types of equipment, while others are unique to one. This will become more apparent as you progress through this course.

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CHAPTER 4

EXPLOSIVES AND AMMUNITION

In this chapter we introduce you to the principles of naval weapons that depend for their functioning on the use of chemical explosives and propellants. These include gun projectiles, torpedo and rocket warheads, and explosive trains in mines and bombs. We will also discuss ammunition storage and sprinkler systems.

EXPLOSIVES AND RELATED MATERIALS

Broadly, if used without further qualification, the term *explosive* includes all those substances that, when initiated by sparks, friction, shock, or other means, undergo a rapid chemical reaction resulting in the formation of gases and the release of a great amount of stored energy. The reaction is accompanied by high pressure and usually by high heat. In this sense, the term explosive is broad enough to include all the substances described in this section. Note, however, that this usage of the term, though broad, excludes as explosive substances such things as high-pressure steam, which may burst a boiler; or high-pressure gas that, under certain circumstances, may rupture its container.

In strictly technical usage, the term explosive includes only those substances that detonate. This means that when their reaction is initiated, they release all their stored energy almost instantaneously with formation of a shock wave. As it appears hereafter in this text, the term explosive will be used in this strict sense only when applied to chemical explosives.

High explosives are classified by their use into three broad groups: (1) primary (initiating) explosives, (2) auxiliary (booster) explosives, and (3) bursting charges. Primary explosives are the most sensitive of high explosives and are used to initiate other charges. They are particularly sensitive to shock, heat, or other physical disturbances and are therefore used in initiating devices such as fuzes (described later in this chapter) to set off chemical reactions in less highly sensitive substances. Boosters are used to initiate explosive charges when the initiating explosion is not sufficient to cause a thorough (high-order) detonation of the main charge. Bursting charges are comparatively insensitive to heat; they are the explosive payload of the projectile, or warhead, initiated by the initiators or boosters. Burster charges damage the target by blast, heat, or fragments of the container such as projectile bodies and bomb cases.

Propelling charges or propellants (sometimes referred to as low explosives) are explosive-like substances that burn rather than detonate. The rate of burning, though rapid compared with the burning of common combustible materials, is much slower than detonation. For instance, a high explosive like TNT detonates at the rate of several thousand yards per second, while a typical gun propellant burns at a rate measured in inches per second. An important characteristic of any propellant's burning rate is that under a given set of conditions, it will always be the same. Propellant burning rate is controllable, and in contrast to explosives that detonate rather than burn, can be predetermined within close limits by adjusting the propellant's composition, the conditions of burning, and related factors.

The distinction between explosives and propellants rests as much on the conditions under which they react as upon the differences in composition. Explosives that normally detonate can be made to burn, under certain conditions not characteristic of their usual application; conversely, under abnormal conditions, propellants can be made to detonate. To illustrate this point, consider gasoline vapor mixed with air. Under optimum conditions in an internal combustion engine cylinder, this mixture burns like a propellant to produce useful thrust. Under less favorable conditions, it detonates with damaging impact, evidenced by a characteristic "knock" or "ping."

For reasons that will become evident later in this text when explosive ordnance is described, practically all explosive and propellant units contain two or more explosives and explosive devices, arranged so that they function in sequence when the unit explodes. This series of stages is called an explosive or propellant train. (See figure 4-1.)

In explosive devices like bombs and gun projectiles, the explosive train typically consists of an initiating device called a detonator. The detonator contains a relatively small quantity of primary explosive, and a booster, which contains a larger quantity of less sensitive explosive that is set off by the functioning of the detonator. The booster detonates the burster, which is the main charge of the device and, in general, is much less sensitive than the preceding stages. In specific devices there are variations on this basic sequence of stages; in small gun projectiles the explosive train is simpler, with the booster omitted or combined with the initiating device, while large aircraft bombs and mines have additional auxiliary stages.

Propelling charges use similar trains. The initiating stage is called a primer, and produces a hot flame which sets off the next stage, called the igniter. The igniter in turn sets off the main charge.

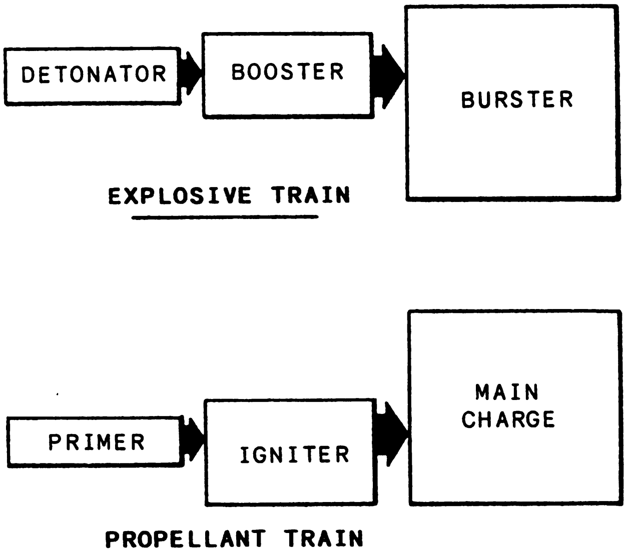


Figure 4-1.—Explosive and propellant trains.

PYROTECHNICS are chemical devices that produce light for illumination or signaling, or smoke for signaling, and may use explosive or propellant substances in performing their functions. Specific pyrotechnic devices used by the Navy are described later in this chapter.

CHEMICAL AGENTS include a variety of gaseous, liquid, or solid substances used for signaling, for harassing or attacking the enemy by asphyxiation or other chemical damage to personnel, or for burning enemy targets. The three main groups of chemical agents are war gases, smokes, and incendiaries. More details on specific chemical warfare devices and substances appear later in this chapter.

DEMOLITION AGENTS are explosives issued and used in specialized demolition equipment other than ammunition. Certain military explosives like TNT are used both in ammunition and in demolition equipment. However, in the requirements of an explosive for demolition and for use in ammunition are not the same. Many explosives, such as Explosive D and nitrostarch respectively, are used either in ammunition, or in demolition equipment, but not in both. The Navy uses demolition explosives in such work as destruction of obstacles or hazards to navigation (such as the sinking of floating hulks), blasting preparatory to construction, destruction of classified equipment if capture by the enemy is imminent, or destruction of designated enemy targets by specially trained personnel such as frogmen.

CHARACTERISTICS OF EXPLOSIVE AND PROPELLANT REACTIONS

The chemical reactions of both explosives and propellants exhibit three distinct characteristics. These characteristics determine the function and usefulness of each compound. They are velocity, heat, and pressure and shock wave.

- **VELOCITY.** An explosive reaction differs from propellant reaction in its velocity. The velocity of combustion of explosives and propellants may vary within rather wide limits, depending upon the type of substance and upon its physical state. The burning rate of colloidal cellulose nitrate powders used as propellants in modern guns is in the order of 24 centimeters per second and up at average gun pressures. The velocity of reaction of high explosives ranges from about 2,000 to 8,500 meters per second.

- **HEAT**. An explosive reaction is always accompanied by the rapid liberation of heat. The amount of heat represents the energy of the explosive, and hence its potentiality for doing work. The quantity of heat given off by an explosive or propellant reaction is not as large as is popularly supposed. A pound of coal, for example, yields five times as much heat as a pound of nitroglycerine. However, coal cannot be used as an explosive, because it fails to liberate heat with sufficient rapidity, and because it does not incorporate an oxidizing agent.

- **GASES**. The main material products (as distinct from energy products) of explosive or propellant reactions are hot gases and a small amount of solid residue. The pressure characteristics of the gases evolved are discussed below; their composition was discussed in the preceding article. In gun barrels, propellant gases have an additional erosive effect, which contributes significantly to the wear of the gun bore.

- **PRESSURE AND SHOCK WAVE**. The high pressure accompanying a propellant or explosive reaction is due to the formation of gases which are expanded by the heat liberated in the reaction. The work that the reaction is capable of performing depends upon the volume of the gases and the amount of heat liberated. The maximum pressure developed and the way in which the energy of the explosion is applied depend further upon the velocity of the reaction. When the reaction proceeds at a low velocity, the gases receive heat while being evolved, and the maximum pressure is attained comparatively late in the reaction. If, in the explosion of another substance, the same volume of gas is produced and the same amount of heat is liberated, but at a greater velocity, the maximum pressure will be reached sooner and will be quantitatively greater. However disregarding heat losses, the work done will be equal.

The rapidity with which an explosive develops its maximum pressure determines its brisance. A brisant explosive is one in which the maximum pressure is attained so rapidly that its shock wave shatters material surrounding it.

INITIATION OF EXPLOSIVE AND PROPELLANT REACTIONS

Explosive and propellant reactions are initiated by the application of some stimulus, which provides energy required to get the reaction started. In general, propellant substances are commonly initiated by heat. The resulting reaction is a burning process, which occurs on the exposed surfaces of the substance and progresses through the mass as each layer is consumed. However, some high explosives will react when sufficient heat is applied, especially if heat is applied suddenly throughout the mass. Initiation by percussion (direct blow) or by friction is a form of initiation by heat derived from the energy of the blow or friction.

High explosives, such as the main charges of mines or torpedoes, in general require the sudden application of a strong shock or detonation to initiate the explosive reaction. This detonation is usually obtained by exploding a smaller charge of a more sensitive high explosive in contact with or close to the main charge.

Detonation of an explosive mass can also be transmitted to other high explosives in the vicinity, without actual contact. The explosion resulting is said to be initiated by influence, and is called a sympathetic explosion. When this happens with mines or depth charges that are located too close together in the water, the phenomenon is called countermining.

The amount of energy necessary to initiate the reaction is the measure of the sensitivity of the explosive or propellant. Sensitivity is important in selecting an explosive for a particular purpose. For example, the explosive in an armor-piercing projectile must be relatively insensitive or the shock of impact will detonate it before penetration. Too much sensitivity is also undesirable because minor shocks or temperature variations incident to normal handling would initiate the reaction.

Sensitivity has little relation to the power developed by a given weight of explosive. TNT, for example, is quite insensitive; but it is pound for pound a much more powerful explosive than mercury fulminate, an initiating compound of great sensitivity.

CLASSIFICATION OF NAVY EXPLOSIVES AND PROPELLANTS BY USE

The following is a brief description of the different classes of Navy explosives and propellants.

These are arranged in the following classifications based in each case on their principal use:

1. **PROPELLANTS.** Propellants are used to propel projectiles from guns, to propel rockets, launch torpedoes, and catapult aircraft. Examples are smokeless powder, ballistite, cordite, and black powder. Figure 4-2 shows propellant grains of various shapes.

2. **PRIMARY (INITIATING) EXPLOSIVES.** The initiation of an explosive reaction requires the application of energy in some form. Propellants are commonly ignited by the application of flame, while explosives are set off by a severe shock. Many primary explosives can be used for initiating either propellants or explosives because they produce both a flame and a shock when exploded.

A PRIMER is used to initiate the burning of a propellant explosive. A simple primer consists of a small amount of lead azide and a small charge of black powder. When fired, the primer produces the flame required to ignite the next component in the train.

A DETONATOR is used to initiate the reaction of a high (disrupting) explosive. It may consist of a charge of lead azide or lead styphnate, either alone or with granular TNT or tetryl in a container. When fired, the detonator produces the shock necessary to initiate the explosive reaction.

3. **AUXILIARY EXPLOSIVES.** Large propellant charges and relatively insensitive high explosives require an intermediate charge so that the increased flame or shock will ensure reaction of the main explosive charge. This auxiliary, when used with propellants, is called an ignition charge. It consists of a quantity of flame-producing black powder. The auxiliary explosive used with high explosives is called a booster. It consists of a quantity of more sensitive high explosive, such as tetryl or granular TNT.

4. **BURSTERS.** Explosives of this classification are all employed to create damage to the target under attack. They are used alone or as part of the explosive charge in mines, bombs, and torpedo warheads, and in projectiles as a burster charge.

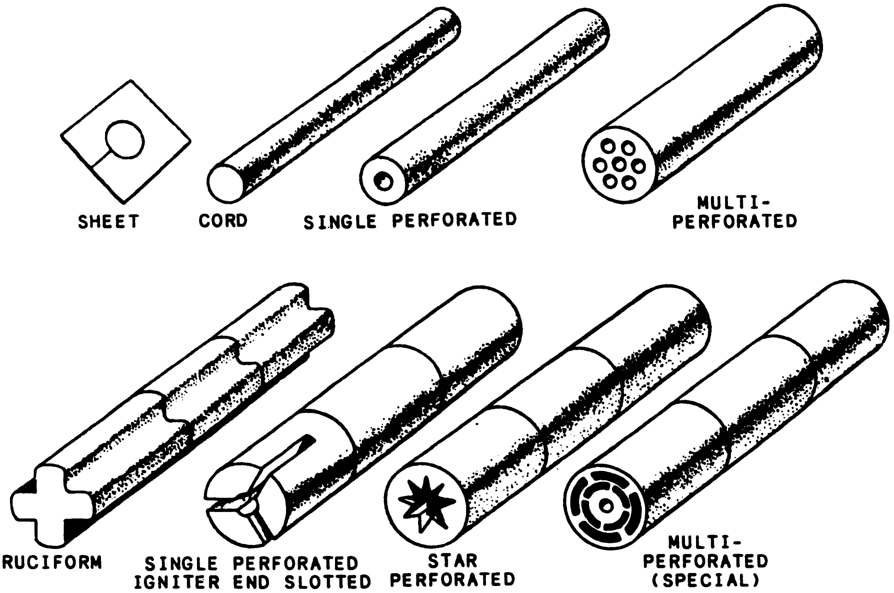


Figure 4-2.—Shapes and forms of propellant grains.

PYROTECHNICS

Pyrotechnics is based on the Greek name for fireworks. The Navy uses pyrotechnics not for celebration but for illumination, and signaling. A pyrotechnic charge is a mixture of chemicals (generally oxidizing agents and combustibles) that reacts to produce light or smoke. Other chemicals may be added to the mixture to color the light or smoke. Some pyrotechnic devices have small quantities of explosive or propellent materials to project the pyrotechnic components in a desired direction, or to scatter them.

The Navy uses a large variety of pyrotechnics; but only a few common examples, all used on surface vessels, will be addressed here.

Illumination Device

The illuminating projectile (colloquially called a "star shell") is a bright-burning flare that is conveyed to the desired location by firing it in a projectile body from a gun. A timing device causes the flare to be ejected from the projectile and ignited. It falls slowly, supported by a parachute. The illuminating projectile is the only pyrotechnic fired from a gun. The light of its flare is intended to illuminate the target and make it easier to aim other guns.

Signaling Devices

Three important pyrotechnic signaling devices are signal lights, Navy lights, and distress signals. Signal lights (often called by their older name of Verylights, but not because they are very light) look like shotgun cartridges, and are fired from a special small projector or a special pistol to a height of about 200 feet. At this point a red, white, or green "star" or small flare will ignite and burn for 5 to 7 seconds. The Navy light is a hand-held flare, either blue or red, which burns steadily for 1 to 3 minutes. The distress signal is a hand-held double-ended affair, which functions like the famous pyre in Exodus, to produce smoke (orange colored) by day (from one end) or a bright light by night (from the other end).

CHEMICAL AGENTS

Chemical agents are of five main types, as described below. They may be used in any of several types of ammunition (depending on the target and the effects desired), or may be released as free liquids or gases from projectors or sprayers. The types are as follows:

Group A. Persistent vesicants. Vesicants blister the skin. The usual ones are mustard gas and lewisite. (Physically, both of these are liquids, not gases.)

Group A-1. Nonpersistent lethal gases. These gases, such as phosgene, injure the body when applied externally, breathed, or taken internally.

Group B. Lacrimators and smokes. A lacrimator such as CH causes weeping and irritation of the throat and lungs. Smokes such as FM and FS are used for screening but have an irritant and, in enclosed spaces, a toxic effect.

Group C. Spontaneously inflammable agents that can be used as incendiaries, such as WP (white phosphorus).

Group D. Readily inflammable mixtures such as TH (thermite), or napalm, a syrupy gasoline-plastic mixture, both of which burn rapidly and with extreme heat and are used as incendiaries.

Chemical warfare is a specialized field and calls for considerable special training. The storage of chemicals requires extraordinary safety precautions. Although poisonous gases were not used in World War II, the Navy was prepared for defense and for reprisal in case the enemy initiated such tactics. Chemical warfare creates many problems in ship protection and decontamination that are the responsibility of the damage control officer and are outside the scope of this book.

DEMOLITION AGENTS

Explosives intended for such uses as blasting, eliminating hazards to navigation and obstacles to amphibious landing, and destroying gear to prevent capture by their enemy, comprise demolition material.

Demolition techniques are taught in special Navy schools and will not be discussed in detail in this text. For major blasting operations, various forms of dynamite are used; but dynamite normally is not carried aboard ship.

Half-pound demolition charge blocks, consisting of either pressed TNT or cast TNT, are issued to ships for general use. Large demolition charges, also consisting of TNT, and assembled with half-pound booster charges, are also issued for major projects, such as scuttling vessels. Charges of both of these types are detonated by means of blasting caps, set off by electric current.

Highly classified instruments must be completely destroyed if capture or abandon ship is imminent. They are therefore equipped with tiny bombs called destructors, which can be actuated at a moment's notice. Usually, they contain lead azide or TNT-tetryl, with appropriate electric ignition elements.

AMMUNITION

In a general sense, ammunition includes anything that is intended to be thrown at the enemy or put in his path, to deter, injure, or kill personnel, or to destroy or damage materials. In this book, the term is used in a much narrower and more technical sense. Ammunition includes any projectile or explosive weapon, as well as components or parts thereof, but not guns or weapon launchers and their parts.

The next section is devoted chiefly to gun ammunition. Other types of ammunition to be taken up later in this book include mines, torpedoes, and submarine weapons, bombs, rockets, grenades, and guided missiles. This text does not address nuclear weapons.

Service ammunition is ammunition fit for service use and including all explosive and propellant components. Inert (i.e., lacking explosive and propellant components) and partially inert ammunition of several types is used for test, training, and practice purposes. Dummy or drill ammunition (completely inert) resembling service ammunition in appearance, size, and weight, may include functioning components that contain no explosive or propellant. It is used for training and test purposes. Cutaway ammunition (completely inert) has a section cut away to show inner construction and components; it is used for training and display purposes. Plaster-loaded or sand-loaded ammunition lacks the explosive burster charge, but is otherwise not inert; it is used for target practice and for testing of launchers, mounts, or projectors.

Two miscellaneous types of ammunition deserve brief mention for the sake of completeness. They are trench-warfare ammunition and blank ammunition. Trench-warfare ammunition includes hand and rifle grenades, mortar projectiles, and similar infantry weapons (issued to Marines and landing forces) for ground combat. Blank ammunition is a type of gun ammunition with propelling charges but no projectile; it is used for saluting batteries, signaling, and training.

IDENTIFICATION

A standard nomenclature and numbering system has been established by the Department of Defense (DOD). This system is a four-digit, alphabetic/numeric code which will be either a Department of Defense identification code (DODIC) assigned by Defense Logistics Services Center (DLSC) or a Navy ammunition logistics code (NALC) assigned by Ship's Parts Control Center (SPCC). A couple of examples of DODIC/NALC nomenclature are as follows:

AMMUNITION TYPE	DODIC/NALC
5″/54 Illumination Projectile	D328
16″/50 BL&P Projectile	D873
12 gauge OO Buckshot	A011

AMMUNITION LOT NUMBERS

When ammunition is manufactured, an ammunition lot number is assigned in accordance with specifications. As an essential part of the lettering, the lot number is stamped or marked on the item, size permitting, as well as on all packing containers. There are presently two ammunition lot numbering systems in the ammunition inventory. The newest lot numbering system was implemented by the Navy in 1978; so there is much ammunition still identified by the old ammunition lot numbering system. Both of these systems are described in the following paragraphs.

Current Ammunition Lot Numbering System

For all ammunition end items and their components, the ammunition lot number consists of a manufacturer's identification symbol, a numeric code showing the year of production, an alpha code representing the month of production, a lot intermix number followed by a hyphen, a lot sequence number, and, when necessary, an alpha character used as an ammunition lot suffix to denote a reworked lot. The following illustrates the construction of a current ammunition lot number:

AMC75D018-124B

where

AMC = Manufacturer's identification symbol

75 = A two-digit numeric code identifying the year of production (1975)

D = A single alpha code signifying the month of production (April)

018 = Lot intermix number

124 = Lot sequence number

B = Ammunition lot suffix (the alpha suffix)

Exceptions to the foregoing system for numbering ammunition lots are given in MIL-STD 1168, section 5.

Old Ammunition Lot Numbering System

The old ammunition lot numbering system consists of the ammunition lot number symbol (ALN), followed by a two-to-three-letter prefix, a sequential lot number, a one-two-three-letter manufacturer's symbol, a two-numeral group, and possibly a lot suffix. An example of an ALN is the following:

BE-374-HAW-78

where

BE = 5-inch, 38-caliber AAC projectile

374 = 374 lot of AAC projectiles assembled

HAW = NAD Hawthorne assembly activity

78 = Assembled during the year of 1978

Prefix Designation. The two-to three-letter prefix designation identifies the size and type of ammunition item. A prefix designation having a final letter "R" denotes renovated items.

Sequential Lot Number. The one-two-four-character group following the prefix indicates the sequential lot number of that particular type produced by an activity during the calendar year. This group consists of numbers 1 through 9999.

Manufacturer's Letters and Numbers. From one to three letters identify the ordnance activity that assembled the ammunition item. Following the symbols is the final numerical group, indicating the last two digits of the calendar year of assembly.

Lot Suffix. An alpha character, following the year of assembly, usually indicates some type of special screening was performed.

Grand-Lot Designation. A grand-lot (GL) designation was assigned to serviceable remnant ammunition items of the same type after serviceability evaluation. These remnant lots are consolidated and reissued under a new ammunition lot number having a grand-lot designation. Grand-lotted ammunition is still in the supply system, but this procedure is no longer used.

COLOR CODES, MARKINGS, AND LETTERINGS

The system of identifying ammunition by the use of color codes, marking, and lettering is intended to be a ready identification to determine the explosive loads and hazards presented by the identified items. A color coding system is employed to indicate the primary use of ammunition, the presence of a hazardous (explosive, flammable, irritant, or toxic) filler, and/or the color of tracers, dye loads, and signals. Color coding for ammunitions of 20-mm and larger are contained in MIL-STD-709, OP 2238 (latest revision), and WS 18782. The lettering, stenciled or stamped on ammunition, includes all the information necessary for complete identification and is marked in compliance with NATO standards and Department of Transportation (DOT) regulations. In addition to standard nomenclature and lot numbers, lettering may include such information as the mark and mod, the type of fuze, and the weapon in which the item

Table 4-1.—Ammunition Color Coding

COLOR	INTERPRETATION
Yellow	1. Identifies high explosives. 2. Indicates the presence of explosives, either, a. sufficient to cause the ammunition to function as a high explosive, or, b. particularly hazardous to the user.
Brown	1. Identifies rocket motors. 2. Indicates the presence of explolsive, either, a. sufficient to cause the ammunition to function as a low explosive, or, b. particularly hazardous to the user.
Gray	Identifies ammunition that contains irritant or toxic agents when used as an overall body color except for underwater ordnance.
Gray With Red Band(s)	Indicates the ammunition contains an irritant (harassing) agent.
Gray With Dark Green Band(s)	Indicates the ammunition contains a toxic agent.
Black	Identifies armor-defeating ammunition, except on underwater ordnance.
Silver/Aluminum	Identifies countermeasures ammunition.
Light Green	Identifies smoke or marker ammunition.
Light Red	Identifies incendiary ammunition or indicates the presence of highly flammable material.
White	Identifies illuminating ammunition or ammunition producing a colored light; exceptions, underwater ordnance, guided missiles, and rocket motors.
Light Blue	Identifies ammunition used for training or firing practice.
Orange	Identifies ammunition used for tracking or recovery.
Bronze	Identifies Dummy/Drill/Inert ammunition used for handling and loading training.
Nonsignificant Colors	
Olive Drab	All ammunition items.
Black	For lettering.
White	1. For lettering. 2. For guided missiles and rocket motors.

is fired. Table 4-1 gives the meaning of the different color codes.

Classification by Size of Gun

Gun ammunition is most commonly classified by the size of the gun in which it is used. In addition to designations of bore diameter, such as 20-mm, 3-inch, or 16-inch, the length of the gun bore in calibers is also used as a means of classification. Thus a 3-inch, 50-caliber projectile is one used in a gun having a bore diameter of 3 inches and a bore length of 50 times 3 inches, or 150 inches.

Classification by Assembly

The three types of ammunition classified by assembly are shown in figure 4-3.

FIXED AMMUNITION.—The fixed class applies to ammunition that has the cartridge case crimped around the base of the projectile. The primer is assembled in the cartridge case. The projectile and the cartridge case containing the primer and propellant charge all form one unit as a fixed round of ammunition. Small arms and guns through the 3-inch/50 use fixed ammunition.

SEMI-FIXED AMMUNITION.—This class applies to ammunition that consists of two units: the projectile assembly and cartridge case assembly. The projectile assembly consists of the projectile body containing the load, nose fuze, base fuze, and auxiliary detonating fuze, as applicable. The cartridge case assembly consists of the cartridge case, primer, propellant charge, wad, distance piece, and a plug to close the open end of the cartridge case. Semi-fixed ammunition is produced for gun sizes of 5-inch through 8-inch.

SEPARATE-LOADING (BAGGED GUN) AMMUNITION.—This class applies to all gun sizes larger than 8 inches. The older cruisers use

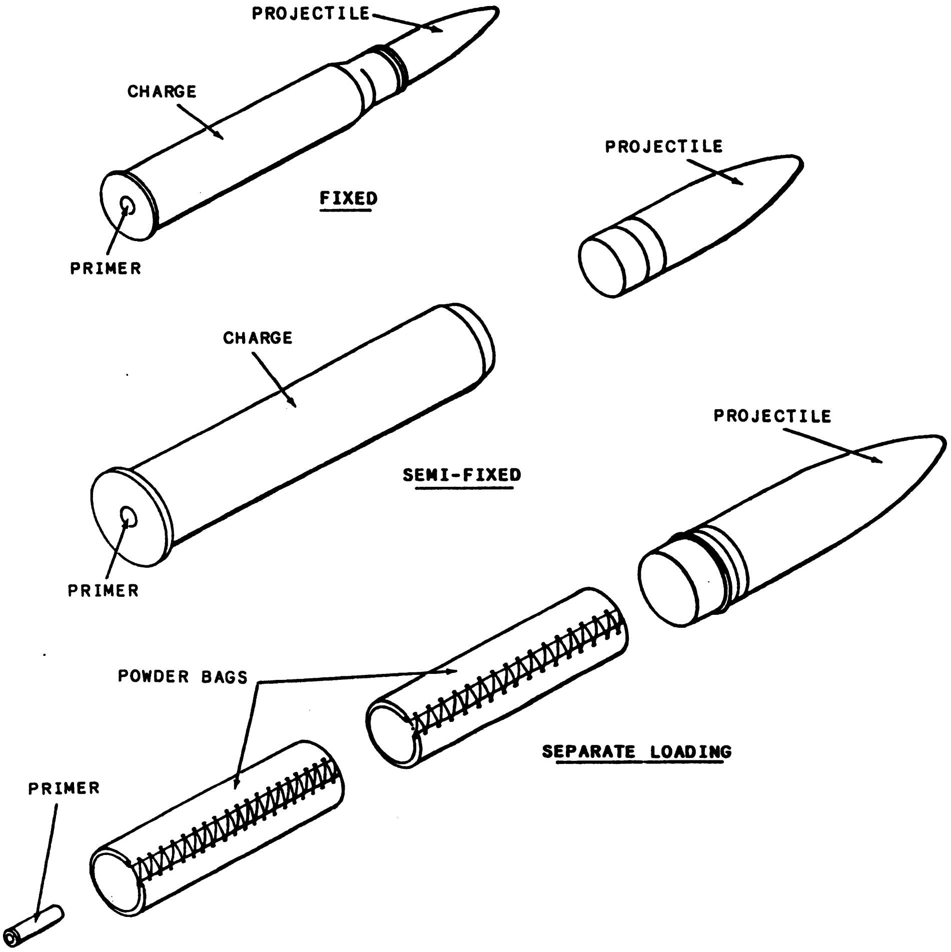


Figure 4-3.—Types of gun ammunition: Fixed (top); Semi-fixed (center); and separate-loading (bagged gun) (bottom).

the separate loading bag-type ammunition, while the newer classes of heavy cruisers use ammunition of the separated type. These two types of ammunition are generally referred to as 8-inch slow fire (SF) for the older bag-type and rapid fire (RF) for the newer separated types. Separate loading ammunition does not contain a cartridge case; the propellant charge is loaded in silk bags which are consumed during the combustion of the propellant when fired from the gun. The projectile, propellant charge, and primer are loaded separately.

GUN AMMUNITION COMPONENTS

Gun ammunition consists of a projectile and a propelling charge. In this section we will describe a typical projectile, the different type of projectiles, propelling charges, and fuzes.

Projectiles

The projectile is that component of ammunition which, when fired from a gun, carries out the tactical purpose of the weapon. While some types of projectiles are one piece, the majority of naval gun projectiles are assemblies of several components. All of the projectiles to be briefly discussed by classification in this chapter have several common features as described in the following paragraphs and as illustrated in figure 4-4.

OGIVE.—The ogive is the curved forward portion of a projectile. The curve is determined by a complex formula designed to give maximum range and accuracy. The shape of the ogive is generally expressed by stating its radius in terms of calibers. It may be a combination of several arcs of different radii.

BOURRELET.—The bourrelet is a smooth, machined area which acts as a bearing surface for the projectile during its travel through the bore of the gun. Some projectiles have only one bourrelet (forward); the rotating band serves as the bearing surface in the rear. Other projectiles have one bourrelet forward and one or two aft, the after one being located adjacent to and either forward and/or aft of the rotating band. Bourrelets are painted to prevent rusting.

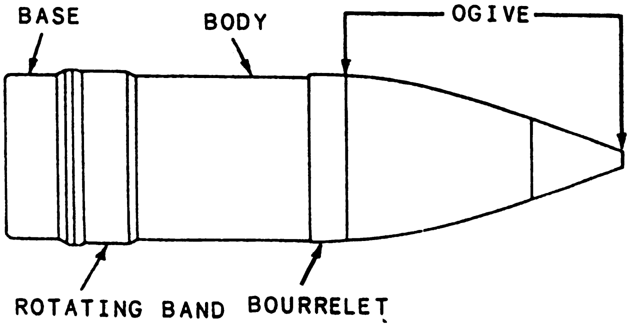


Figure 4-4.—Typical projectile, external view.

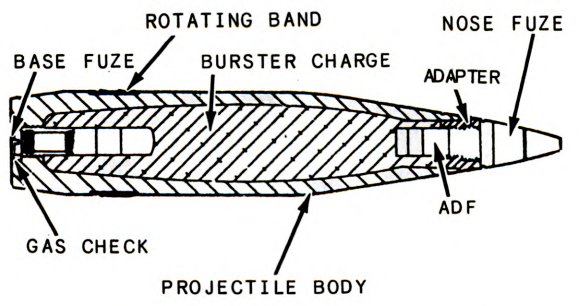
BODY.—The body is the main part of the projectile and contains the greatest mass of metal. It is made slightly smaller in diameter than the bourrelet and is given only a machine finish.

ROTATING BAND.—The rotating band is circular and made of commercially pure copper, copper alloy, or plastic seated in a scored cut in the after portion of the projectile body. For all minor and medium caliber projectiles, rotating bands are made of commercially pure copper or gilding metal, which is 90-percent copper and 10-percent zinc. Major caliber projectile bands are of cupro-nickel alloy, containing 2.5-percent nickel or nylon with a Micarta insert. As a projectile with a metallic band passes through the bore of the gun, a certain amount of copper will be wiped back on the rotating band and will form a skirt of copper on the after end of the band as the projectile leaves the muzzle of the gun. This is known as fringing and is prevented by cutting grooves, called cannelures, in the band or by undercutting the lip on the after end of the band. These cuts provide space for the copper to accumulate. The primary functions of a rotating band are: (1) to seal the forward end of the gun chamber against the escape of the propellant gas around the projectile; (2) to engage the rifling in the gun bore and impart rotation to the projectile; and (3) to act as a rear bourrelet on those projectiles which do not have a rear bourrelet.

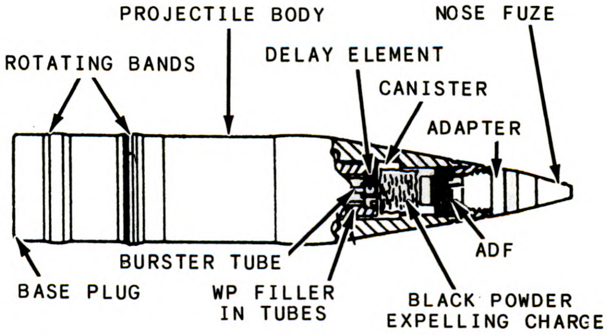
BASE.—The base is the after end of the projectile. A removable base plug is provided in projectiles that are loaded through this end. A fuze hole may be drilled and tapped in the center of this base plug. Projectiles with large openings in the nose for loading through that end require no base plug. In such cases, however, the solid base of the projectile may be drilled in the center to receive a base fuze or tracer if desired. The edge formed by the side walls and the base is usually broken slightly to give additional range. Some projectiles are tapered aft of the rotating band, a shape known as boat-tailed. Projectiles with plastic bands may have full caliber boat-tails for optimum aerodynamic shape.

PROJECTILE TYPES

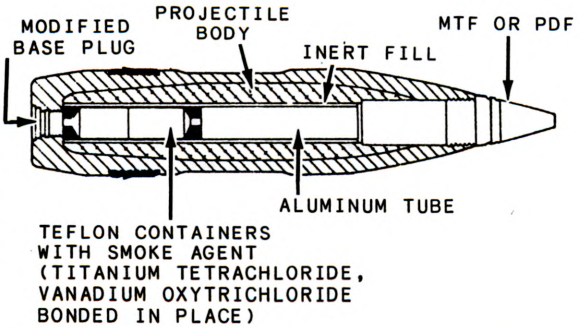
Projectiles are also classified by their tactical purpose. The following are descriptions of the common projectile types (fig. 4-5).



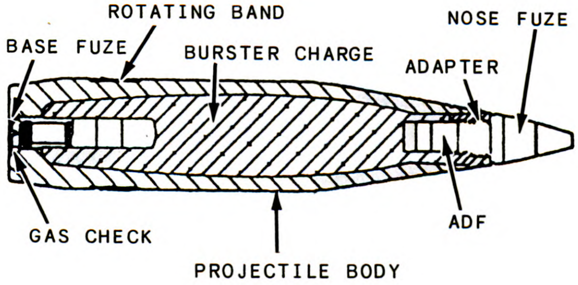
A. 5-INCH, 54-CALIBER ANTIAIRCRAFT COMMON PROJECTILE



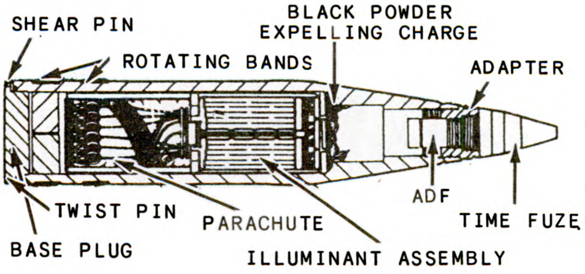
B. 5-INCH,54-CALIBER WHITE PHOSPHORUS PROJECTILE


MODIFIED BASE PLUG
PROJECTILE BODY
MTF OR PDF
INERT FILL
ALUMINUM TUBE
TEFLON CONTAINERS WITH SMOKE AGENT (TITANIUM TETRACHLORIDE, VANADIUM OXYTRICHLORIDE BONDED IN PLACE)

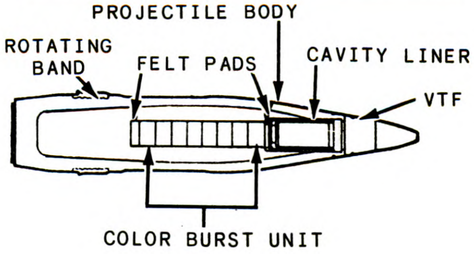
C. 5-INCH, 54-CALIBER TARGET PRACTICE(PUFF) PROJECTILE



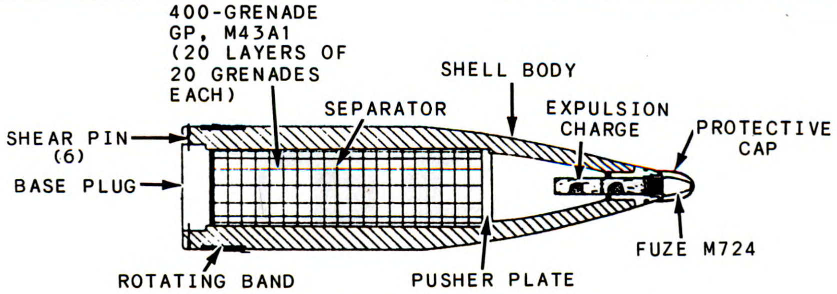
D. 5-INCH, 54-CALIBER HIGH CAPACITY PROJECTILE



E. 5-INCH, 54-CALIBER ILLUMINATING PROJECTILE



F. 5-INCH, 54-CALIBER NONFRAGMENTING PROJECTILE



G. 16-INCH, 50-CALIBER ANTIPERSONNEL PROJECTILE

Figure 4-5.—Common projectile types.

ANTIAIRCRAFT (AA).—AA projectiles are designed for use against aircraft; they have no base fuze. Otherwise, they are substantially the same as the high capacity (HC) projectiles described below.

ANTIAIRCRAFT COMMON (AAC).—AAC projectiles are dual-purpose projectiles combining most of the qualities of the AA-type with the strength necessary to penetrate mild steel plate (fig. 4-5, view A). However, AAC projectiles do not have the penetrative ability of Common projectiles. The type of fuzing will depend on the use. Fuze threads are provided in the nose and in the base. AAC projectiles are normally equipped with a mechanical time fuze (MTF) and an auxiliary detonating fuze (ADF). Dual-purpose action is accomplished by a time setting for air burst or by setting MTFs on "safe" or for a time longer than flight-to-target to permit the base detonating fuze (BDF)(delay) to function for penetration. By substituting a point detonating fuze (PDF) for the MTF, these projectiles are converted to high capacity for surface burst.

ARMOR-PIERCING (AP).—AP projectiles are designed to penetrate their caliber of Class A armor plate. They are characterized in most cases by a low explosive-charge-to-total-weight ratio and by their windshields and AP caps. Windshields are light nose pieces of false ogivals designed to give suitable flight characteristics; they are made of mild steel, steel stamping, or aluminum. Windshields are screwed to the AP cap and are staked in place. AP caps are made of the same kind of steel as the projectile bodies. The cap breaks down the initial strength of the armor plate and provides support to the pointed nose of the projectile as it begins to penetrate the target. The cap also increases the effective angle of obliquity at which the projectile may hit and penetrate. The cap is peened and soldered to the nose. AP projectiles are fuzed only in the base. The fuzes must not be removed, except at ammunition depots. Powdered dye colors are loaded in the windshield of most AP projectiles. These dye colors allow a firing ship to identify its splashes, since each ship is assigned a specific color. The dye is placed inside the windshield in a paper container. There are ports in the forward portion of the windshield that admit water when the projectile strikes the surface and breaks the port seals. Other ports in the after portion of the windshield are pushed out by pressure of the water inside the windshield. The dye is dispersed through these after ports.

COMMON (COM).—COM projectiles are designed to penetrate approximately one-third their caliber of armor. They differ from AP projectiles in that they have no hardened cap and have a larger explosive cavity.

CHEMICAL.—Chemical projectiles may be loaded with a toxic, harassing, or smoke-producing agent. Of the smoke agents, white phosphorous (WP) is the most frequently used. WP projectiles (fig. 4-5, view B) are designed to produce heavy smoke and, secondarily, an incendiary effect. The small WP containers are expelled and then scattered by a delayed action burster charge that is ignited by a black powder expelling charge. Other chemical loads are dispersed in a similar manner.

PUFF.—Puff projectiles (fig. 4-5, view C) are nonexplosive projectiles used as practice (spotting) rounds. They are designed to produce dense smoke clouds approximating those of high explosive rounds.

DRILL.—Drill projectiles are used by gun crews for loading drills and for testing ammunition hoists and other ammunition handling equipment. They are made of economical, but suitable metals, and are designed to simulate the loaded service projectile represented as to size, form, and weight. They may be solid or hollow. If hollow, they may be filled with an inert material to bring them to the desired weight. This latter type is closed with a base or nose plug or both, as appropriate.

DUMMY.—Dummy projectiles are reproductions of projectiles that may be produced from a variety of materials for a number of purposes. Drill projectiles are dummy projectiles in that they are not to be fired from a gun; however, all dummy projectiles are not drill projectiles. Dummy projectiles may be made for display, instruction, or special tests.

HIGH CAPACITY (HC).—HC projectiles are designed for use against unarmored surface targets, shore installations, or personnel. They have a medium wall thickness and large explosive cavities. Large HC projectiles (fig. 4-5, view D) are provided with an auxiliary booster to supplement the booster charge in the nose of the main charge. With threads in both the nose and base, HC projectiles may receive a variety of fuzes or plugs to accomplish different tactical purposes.

An adapter ring (or rings) is provided on the nose end of most HC projectiles to allow installation of PDFs or nose plug and ADFs with different size threads. An adapter is removed for larger fuzes. HC projectiles are normally shipped with a PDF installed in the nose. The base fuze that is shipped installed in the projectile may not be removed except at an ammunition depot.

HIGH EXPLOSIVE (HE).—Small caliber projectiles with an HE designation are designed to receive a large explosive charge. Structurally, they resemble the high capacity type in larger caliber projectiles. They have no base fuze; a nose fuze is issued installed in the projectile.

HIGH EXPLOSIVE-POINT DETONATING (HE-PD).—These projectiles feature PDFs, which may require the use of an ADF and fuze cavity liner (FCL). If the PDF is of the new, short-intrusion type, no ADF is required since its function has been incorporated. Also the FCL has been integrated with a fuze thread adapter in some cases.

HIGH EXPLOSIVE-VARIABLE TIME (HE-VT).—These projectiles may be fuzed with either the short-intrusion variable time fuze (VTF) and adapter or with the deep-intrusion fuze and FCL.

HIGH EXPLOSIVE-MECHANICAL TIME/ POINT DETONATING (HE-MT/PD).—This projectile is similar to the HE-MT projectile except that the nose time fuze has a point detonating backup that causes a self-destructive action on surface impact in case of airburst function failure, due to clock failure or surface impact before expiration of the set time.

ILLUMINATING (ILLUM).—ILLUM projectiles (fig. 4-5, view E) are made with thin walls. Each contains a time fuze, an ADF, a small black powder expelling charge behind the ADF, an assembly consisting of a pyrotechnic star or candle with a parachute, and a lightly held base plug. The time fuze serves to ignite the expelling charge. Explosion of the expelling charge forces out the base and the illuminating assembly, and ignites the star or candle.

ROCKET ASSISTED PROJECTILE (RAP).—To increase the range and effectiveness of 5-inch gun systems, the RAP was developed as an addition to existing gun-type ammunition. It has a solid-propellant rocket motor which can impart additional velocity and provide extended range compared to standard projectiles.

SELF-DESTRUCT, NON-SELF DESTRUCT (SD, NSD).—Certain older projectiles used in antiaircraft firing have a feature which detonates the explosive filler at a designated range to prevent the round from hitting other ships in the task force. Some VTFs contain this self-destructive device. Also, some tracers in small caliber projectiles are made to burn through to the explosive filler. In either case, the projectile carries the designation SD. Projectiles without one of these features are designated NSD.

TARGET (TAR).—These are blind loaded (BL) projectiles. They are special projectiles designed for target practice, ranging, and proving ground tests. As target practice ammunition, they are used to train gunnery personnel. They may be fitted with a tracer (BL-T) or plugged (BL-P).

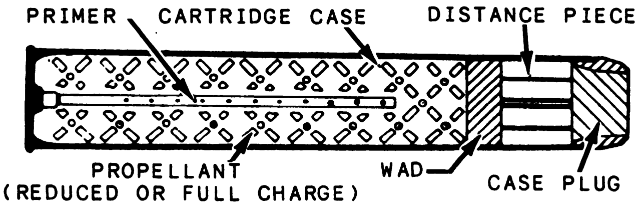
VARIABLE TIME NONFRAGMENTING (VT-NONFRAG).—Some VT-NONFRAG projectiles (fig. 4-5, view F) are loaded to avoid rupturing the body and spreading fragments when the fuze functions; however, sometimes the projectile ogive breaks up into low velocity fragments. They are designed for use in antiaircraft target practice, particularly against expensive drone targets, for observing the results of firing without frequent loss of the drones. These projectiles have fillers of epsom salts or other inert material to give the projectile the desired weight. A color-burst unit, consisting of pellets of black powder and a pyrotechnic mixture, is placed in a cavity drilled into the center of the inert filler. The color burst is ignited through the action of the nose fuze and the black-powder pellets. The color-burst unit may be one of several colors that exits through the fuze cavity and ruptured projectile.

ANTIPERSONNEL.—The antipersonnel projectile (fig. 4-5, view G) consists of a projectile body, an expulsion charge, a pusher plate, a payload of 400 individually fuzed grenades, and a base plug. The M43A1 grenade is an airburst rebounding-type munition. The antipersonnel projectile is unique to the 16″/50 gun.

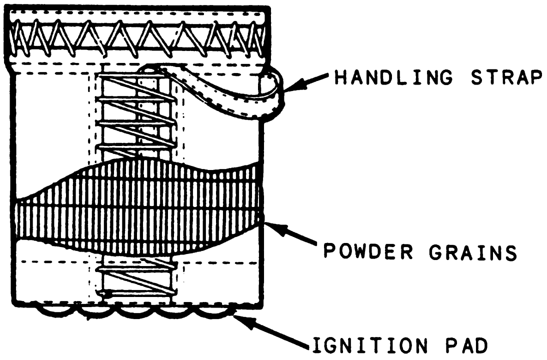
Propelling Charges

Propelling charges are mixtures of explosives designed to propel projectiles from the gun to the target. In fixed ammunition, the propelling charge and projectile are assembled together in a case and handled as one unit; the principal component parts are the brass or steel cartridge case, the primer, and the propellant powder charge. In the separated ammunition, the propelling charges and projectile are assembled separately; they are stored and handled as separate units until they are loaded into the gun. The propelling charge of the separated ammunition round consists of the propellant primer, details, and closure plug assembled into the metal case. The propelling charges of separate loading ammunition are made up in sections (bag charges) separate from the projectile and primer. Propelling charges for all calibers of ammunition have some common features. There are two basic categories into which these features can be grouped—case ammunition and bag charges. Saluting, reduced, and clearing charges have components that are the same as case ammunition; so they are included with case ammunition.

CASE AMMUNITION.—Propelling charges for small and medium caliber guns are assembled with primer and powder enclosed in a brass or steel container called a cartridge case (fig. 4-6, view A). Assembly of the entire charge in a single, rigid, protective case increases the ease and rapidity of loading and reduces the danger of flare-backs. Also, the case prevents the escape of gases toward the breech of the gun; it expands from the heat and pressure of the burning powder and forms a tight seal against the chamber.



A. 5-INCH, 54-CALIBER PROPELLING CHARGE



B. BAG AMMUNITION FOR A 16-INCH GUN

Figure 4-6.—Propelling charges.

REDUCED CHARGE.—A reduced charge is one in which less than the service load of powder is placed in the cartridge case. Reduced charges may be employed in target practice to decrease the wear on the gun.

CLEARING CHARGE.—When a round fails to seat fully upon being rammed into the gun chamber, thus preventing closure of the breech, or when the propelling charge fails to function, the projectile may be fired by extracting the full-sized case and loading a clearing charge, which is shorter.

SALUTING CHARGE.—These are charges used when firing a gun to render honors. Since no projectile is involved in such firing, the charge consists of a cartridge case containing a black powder load and a primer. The ships normally employ 40-mm or 3-inch guns for saluting. Saluting charges for the 40-mm and the 3-inch guns are issued completely assembled, with no replacement components.

BAG CHARGE.—In large guns using separate loading ammunition, the propellant charge is made up of sections of powder contained in cylindrical cloth bags (fig. 4-6, view B) which approximate the inside diameter of the gun chamber in which they are to be used. In most cases, more than one section (bag) is required. For example, the 8-inch, 55-caliber gun uses a propellant charge consisting of two sections, while the 16-inch, 50-caliber gun uses a propellant charge of six sections. In these guns the leaking of gases from the chamber is checked by the mushroom and pads on the breech plug. The breech plug also contains a lock, which receives the separately loaded primer.

Fuzes

The component that sets off the projectile bursting charge is the fuze. No matter how complicated or simple the construction or function of the fuze is, it always serves the same purpose.

As we saw in chapter 3, all fuzes use the force of inertia for arming, and in most cases, operation. Each type of fuze has a different tactical use. These uses and a detailed functional description will not be covered in this text. For more information on ammunition types and their fuzes, refer to *Navy Gun Ammunition,* SW030-AA-MMO-010.

Fuzes can be generally classified by functions as discussed in the following paragraphs.

TIME FUZES.—Mechanical time fuzes (MTFs) function a predetermined length of time after the projectile is fired. The exact time is set, before the projectile is loaded into the chamber, by a mechanical fuze setter on the mount. Or you can set the fuze with a special fuze wrench. The interval between the instant the fuze is set and the instant the projectile is fired is dead time. No matter when, how, or by what it is set, the timing mechanism of a time fuze will not function until the projectile is fired.

PROXIMITY FUZES.—Proximity, or variable time (VT), fuzes are energized after the projectile is fired and function when the projectile approaches closely to the target.

PERCUSSION FUZES.—Percussion, or impact, fuzes function either as the projectile strikes the target or (especially an AP projectile) after the projectile penetrates. Some fuzes (nondelay type) function immediately on contact with any thin material (for example, the thin sheet metal skin of an aircraft). Fuzes for armor-piercing projectiles, however, always incorporate a slight delay to keep the burster from going off until after penetration. These percussion fuzes can be located either on the nose (PDF) or the base (BDF) of the projectile.

COMBINATION FUZES.—Combination fuzes incorporate both time and percussion features—that is, the fuze may go off either on impact, or after the time set, whichever occurs first.

AUXILIARY FUZES.—Auxiliary fuzes (ADF), as the name implies, operate only with other fuzes. In gun projectiles they form part of the explosive train and pass on the explosion initiated by another fuze (located in the projectile nose) to the main bursting charge.

MAGAZINES

The term *magazine* applies to any compartment, space, or locker which is used, or intended to be used, for the stowage of explosives or ammunition of any kind.

The term *magazine area* includes the compartment, spaces, or passages on board ship containing magazine entrances, which are intended to be used for the handling and passing of ammunition. The term is also used to denote areas adjacent to, or surrounding, explosive stowages, including loaded ammunition lighters, trucks, and railroad cars, where applicable safety measures are required.

Magazines are arranged with regard to facility of supply, the best obtainable protection, and the most favorable stowage conditions.

MAGAZINE TYPES

Many different types of magazines are provided on ships. Each magazine is designed specifically for the type of ammunition it is to contain. For our purpose, however, we will be concerned with only three types—primary magazine, ready-service magazine, and ready-service stowage.

Primary Magazines

Primary magazines are designed as ammunition stowage spaces, generally located below the main deck, and insofar as is practicable, below the waterline. They are adequately equipped with insulation, ventilation, and sprinkler systems. These spaces must be provided with fittings so that they may be locked securely. Primary magazines accommodate a vessel's complete allowance of ammunition for peacetime operation.

Ready-Service Magazines

Ready-service magazines are spaces physically convenient to the weapons they serve. They provide permanent stowage for part of the ammunition allowance. Normally they are equipped with insulation, ventilation, and ammunition sprinkler systems, and should be secured by locking. The combined capacities of primary and ready-service magazines are normally sufficient to stow properly the allowance for war and emergencies.

Ready-Service Stowage

Ready-service stowages are those ammunition stowage facilities in the immediate vicinity of the weapon served. They include weather deck lockers, bulwark (gun shield) racks, and 5-inch upper handling rooms. This stowage normally is filled only when the weapon is to be fired. There is little security for ammunition in such stowage, and it provides the least favorable protection from the elements.

AMMUNITION HANDLING AND SAFETY

The utmost care and prudence must be exercised in supervising the handling, inspecting, preparing, assembling, and transporting of all types of ammunition. People tend to become careless and indifferent when continually engaged in work with explosives and, as long as nothing occurs, are inclined to drift gradually into neglecting the necessary precautions. Nothing but constant vigilance on the part of the officers and petty officers in charge will ensure the steadfast observance of the rules and regulations which experience has taught to be necessary.

Safety is everyone's responsibility. Awareness of danger, knowledge of how danger can be avoided, and constant vigilance are the three basic requirements to prevent accidents when working with explosives. If a thorough understanding of the basic ideas behind the precautions is developed, unsafe conditions can be recognized and corrected and further suitable action can be taken instinctively when the unexpected occurs. Safety precautions pertaining to the handling of and working with explosives may be found in OP 4, *Ammunition Afloat*; OP 5, *Ammunition Ashore*; OP 1014, *Ordnance Safety Precautions, Their Origin and Necessity*; and OP 3347 *United States Ordnance Safety Precautions*.

Safety precautions, rules, and regulations for handling explosives should be made the subject of frequent review, and the necessity for strict compliance with these precautions should be firmly fixed in the minds and habits of all hands involved in handling explosives so they will react in an emergency to the instruction previously received.

Attention is invited particularly to the fact that in the early stages of the use of explosives, experience was gained at a great price—not only in dollars, but in human lives. No relaxation should be tolerated, since this tends to create the impression that the rules are arbitrary.

MAGAZINE SPRINKLER SYSTEMS

Sprinkler systems are used for emergency cooling of, and firefighting in, magazines, ready-service rooms, ammunition, and missile handling areas. A magazine sprinkler system consists of a network of pipes secured to the overhead and connected by a sprinkler system control valve to the ship's saltwater firemain. The pipes are fitted with spray heads or sprinkler head valves, which are arranged so that the water forced through them showers all parts of the magazine or ammunition and missile handling areas. A modern sprinkler system can wet down all exposed bulkheads at the rate of 2 gallons per minute per square foot and can sprinkle the deck area at the rate of 4 gallons per minute per square foot. Magazine sprinkler systems are designed so that they are capable of completely flooding their designated spaces within an hour. To prevent unnecessary flooding of adjacent areas, all compartments equipped with sprinkler systems are watertight. Upper deck handling and ready-service rooms are equipped with drains that limit the maximum water level to a few inches. Magazines are completely enclosed; if flooded, they would be exposed to the full firemain pressure. The firemain pressure on most ships is considerably higher than the pressure that magazine bulkheads could withstand; therefore, magazines are equipped with exhaust ventilators that are located in the bulkhead near the overhead. An exhaust ventilator is a pipe with a check valve that permits pressure release (usually to the topside). Since the diameter of the pipe is large enough to allow water to flow out as fast as it flows in, no excess pressure can build up in the magazine compartment.

Magazines are also equipped with small, capped drainpipes located in the bulkhead near the deck. The caps may be removed in the adjacent compartment to drain flooded magazines.

In their complexity, the sprinkler system control valve and associated components vary with the type of ship, type of stowage, and type of ammunition or missile stowed in the magazine.

There are two basic types of hydraulically controlled sprinkler systems—the saltwater/seawater-operated, dry-type, and the saltwater/seawater-operated wet-type. Both types may be found on the same ship. However, the dry-type is normally installed in gun ammunition magazines and the wet-type installed in missile magazines. Technical information on both types is contained in NAVSEA 0910-LP-000-7320, *Magazine Sprinkler Systems.*

Both types are normally tested monthly and flushed quarterly. As division officer, you may be required to witness the testing of these systems. Therefore, you must have a basic understanding of the systems major components. We will now describe the functions of a pneumatically released pilot valve (PRP) and a heat sensing device (HSD).

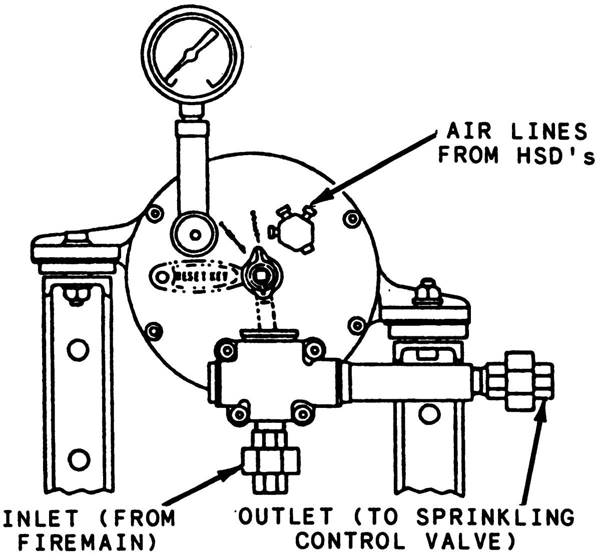


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Figure 4-7.—Pneumatically released pilot valve.

PNEUMATICALLY RELEASED PILOT (PRP) VALVE

This valve (fig. 4-7) is a normally closed spring-loaded pilot valve, which opens automatically to actuate the magazine sprinkler system in response to a pneumatic signal from one or more thermopneumatic elements.

The main components of the PRP valve are the operating mechanism and compensating vent, which are housed within a circular bronze case, and the pilot valve, which is mounted on the front of the case. The pilot valve is installed in a 3/8-inch line, which connects the firemain to the sprinkler system hydraulic control system piping. The PRP valve case is provided with shock mounts and brackets for fastening to a bulkhead.

The pilot valve lever is designed to pivot about a pin fastened to the PRP valve case. When the PRP valve release diaphragm is tripped, the movement of the pilot valve lever causes the seat holder to move away from the seat, thereby permitting seawater to enter the hydraulic control system piping and actuate the sprinkler system.

The compensating vent (fig. 4-8) functions to "leak off" the slight increases or decreases of pressure within the HSDs caused by normal temperature fluctuations in the protected compartment. This leakoff of slow pressure changes equalizes the pressure on both sides of the release diaphragm and prevents inadvertent tripping of the PRP valve.

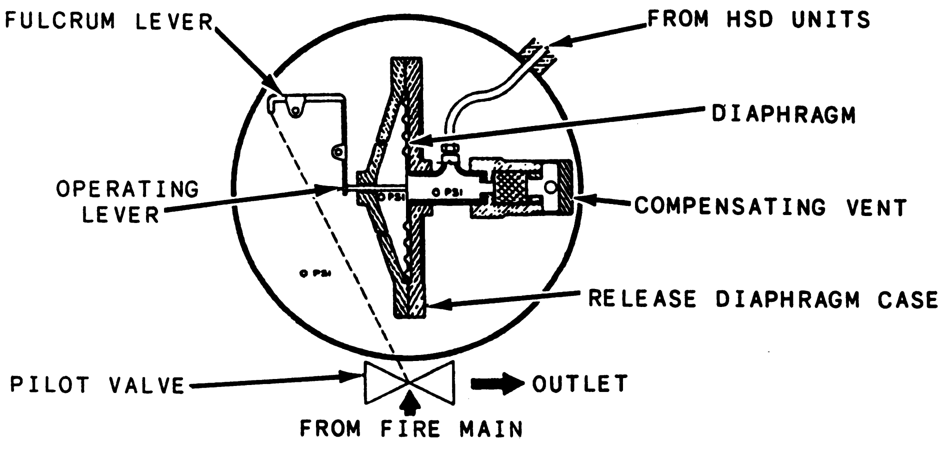

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Figure 4-8.—Pneumatically released pilot valve (PRP), schematic.

HEAT-SENSING DEVICE (HSD)

This device (fig. 4-9) is a thin-walled, spring-loaded bellows containing air that is designed to create a pressure in response to either a rapid or slow rise in temperature.

HSDs are mounted on the overhead of the protected space and are connected to the manifold by individual 1/8-inch transmission lines. A circle seal check valve is installed in each transmission line.

In the event of a fire causing a rapid rise in temperature in the protected space, heat is absorbed by the HSD. The heat is conducted to the air within the bellows causing it to expand and create a pressure. The pressure is transmitted to the rear of the release diaphragm of the PRP valve, thereby creating the differential pressure necessary to trip that valve.

In the event of a smoldering fire causing a slow rise in temperature in a protected space, the pressure created within the bellows increases too slowly to trip the PRP valve. When the temperature reaches 160 °F, the fusible link in the end of the collet melts, thereby removing the restraint holding the bellows. The bellows then collapse under the tension of the spring. The sudden compression creates a pressure impulse, which is transmitted to the rear of the release diaphragm of the PRP valve, thereby creating the differential pressure necessary to trip that valve.

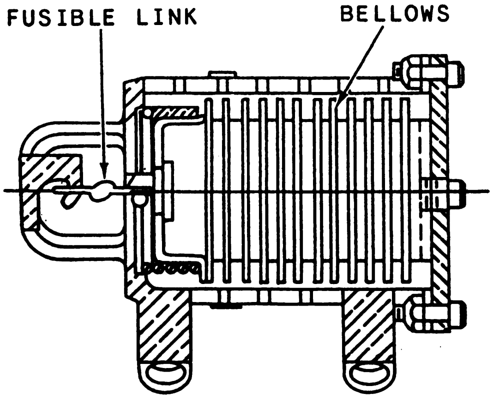

Figure 4-9.—Heat sensing device (HSD).

SUMMARY

In this section we have described explosives and the types of ammunitions using them. We have also briefly discussed ammunition storage and magazine protection systems. Each topic is considered basic in the naval ordnance world. You, as the division officer, will have to familiarize yourself with the types of ammunition, ammunition storage, and handling requirements, and magazine protection systems for which your division is responsible. You will be required to keep records and submit periodic reports on the ammunition in your cognizance. These reports and records are covered in chapter 15.

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CHAPTER 5

GUNS, GUN MOUNTS, AND TURRETS

The guns aboard modern naval vessels, though complex in detail, are made up of basic components varying little from one gun to the next. In this chapter we will describe these common components and how they function. We will then briefly describe each of the gun systems in the fleet today. We will conclude with a section on some common gun maintenance procedures and pre-fire requirements.

GUN COMPONENTS

Every gun system includes equipment used for gun positioning, loading, and firing. Loading equipment varies greatly in design from gun to gun, but its purpose remains the same—to load a complete round in the gun chamber for firing. We will describe the various loading systems later in this chapter. The greatest similarities from one gun to the next are found in the positioning and firing components that we will now describe.

POSITIONING EQUIPMENT

Positioning equipment includes all the machinery used to support and move the gun tube to the desired **train** (horizontal) and **elevation** (vertical) angle. This includes the stand, base ring, trunnions, carriage, and slide as shown in figure 5-1.

- **Stand**—The stand is a steel ring bolted to the deck, which serves as a foundation and rotating surface for movement in train. The stand contains both the train bearings and the training circle. The training circle is a stationary internal gear that the train drive pinion "walks around" to move the gun in train.

- **Base Ring**—The base ring is also called the lower carriage. It is the rotating platform, supported by the stand, which supports the upper carriage.

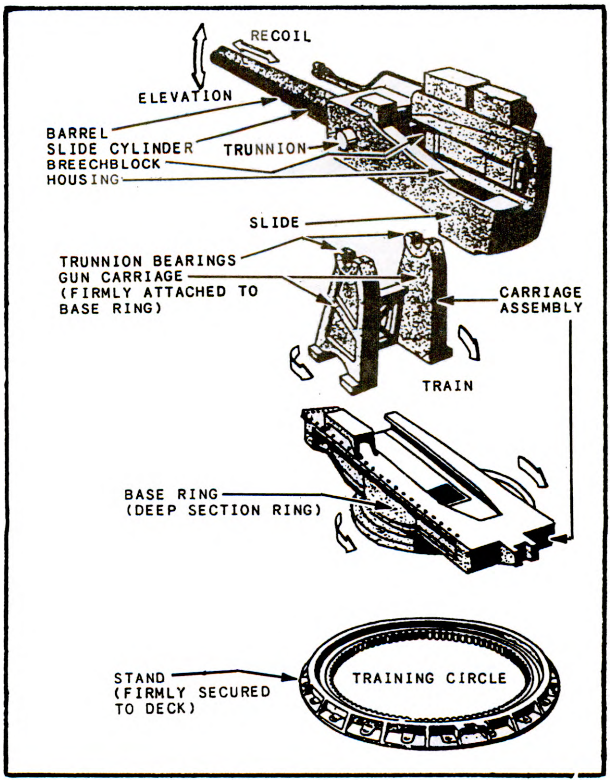

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Figure 5-1.—Gun-positioning equipment.

- **Gun Carriage**—The gun carriage is also called the upper carriage. It is a massive pair of brackets that holds the trunnion bearings. The trunnion bearings support the trunnions, which are part of the slide, together forming the elevation pivot point.

- **Slide**—The slide is a rectangular weldment that supports all the elevating parts of the gun.

FIRING EQUIPMENT

The firing equipment includes all the components necessary to allow the gun to safely fire,

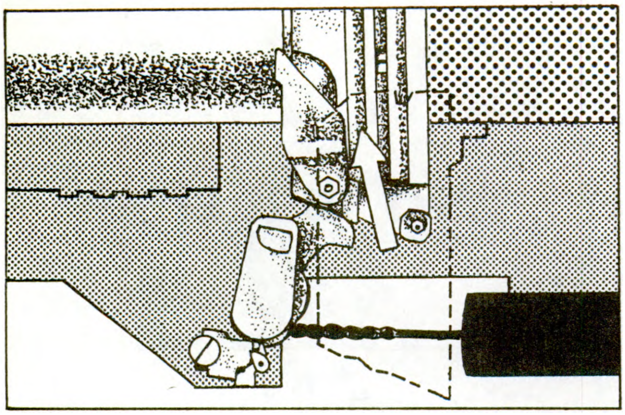

Figure 5-2.—The sliding wedge breechblock of a 5″/38 gun.

absorb the shock of recoil, and reposition for further firing. This includes the housing, breechblock, recoil, and counterrecoil systems.

- **Housing**—The housing is a large steel casement in which the barrel and breechblock are fitted. The housing moves in recoil inside the slide.

- **Breechblock**—The breechblock seals the breech end of the barrel (remember the definition of a gun). Breechblocks are of two different types—sliding wedge or interrupted thread. The sliding wedge consists of a machined steel block that slides in a grooved way in the housing to cover the breech opening. The grooves are slanted so that the breechblock moves forward as it covers the back of the casing, wedging it in place. The interrupted thread breech plug closes similar to the way a bayonet lug camera lens is installed. The

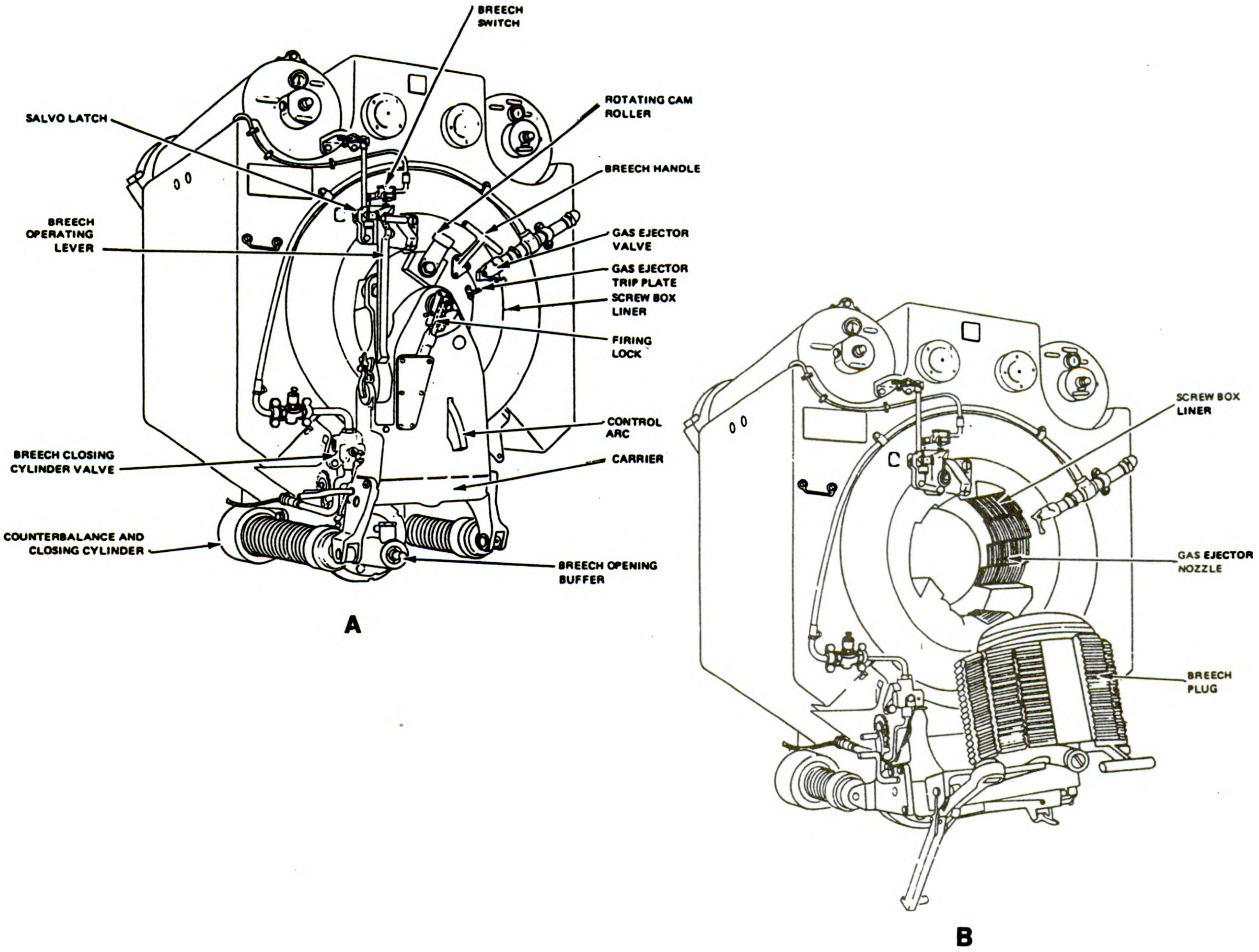

Figure 5-3.—A 16″/50 breech mechanism Mk 4 Mod 0. A. Closed; B. Open.

lugs on the plug are cut to allow it to be inserted into the grooves cut in the threaded breech. Once inserted, the plug is turned 120 degrees and locked in place. All guns currently in use, except the 16″/50, use the sliding-wedge type breechblock. The two types are illustrated in figures 5-2 and 5-3, respectively.

- **Recoil System**—(fig. 5-4) Normally, a recoil system consists of two stationary pistons attached to the slide, set in a liquid filled cylinder in the housing. As the housing moves rearward in recoil, the trapped liquid is forced around the piston head through metered orifices slowing the movement of the housing.

- **Counterrecoil System**—A counterrecoil system consists of a piston (or pistons) set in a pressurized cylinder. As the gun recoils, the piston protrudes further into the cylinder. After the force of recoil is spent, the air pressure, acting against the piston, pushes the housing back into **battery** (the full forward position). The piston may be attached to the slide, allowing the cylinder (which is machined into the housing) to slide over it during recoil. This configuration is used on the older 5″/38 gun (fig. 5-5). Later

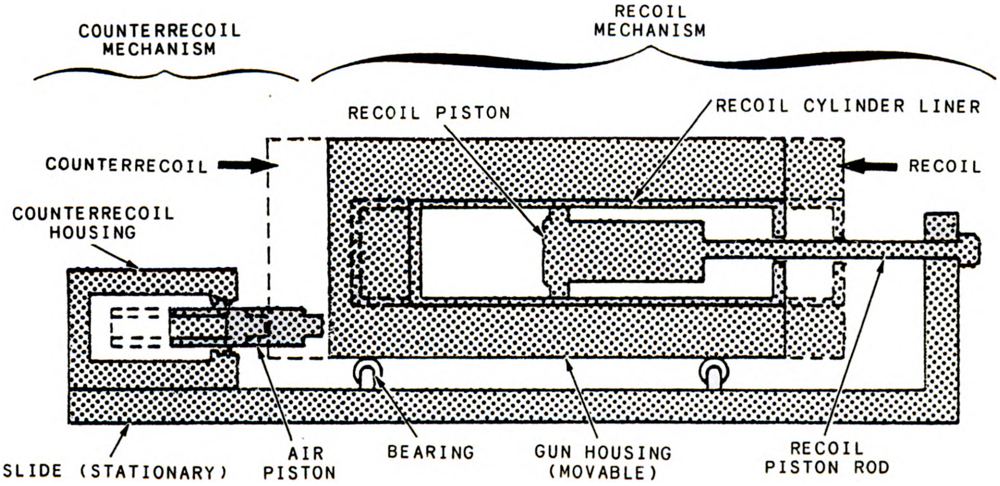

Figure 5-4.—Recoil and counterrecoil systems.

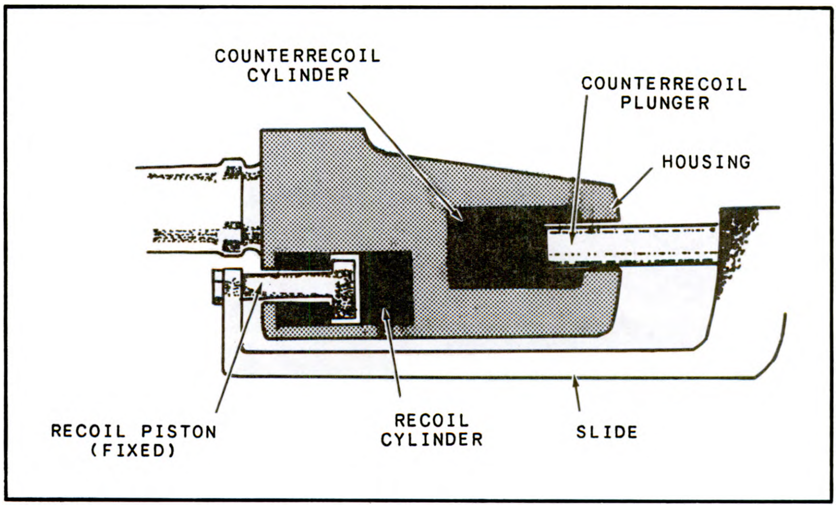

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Figure 5-5.—5″/38 recoil and counterrecoil systems.

guns use two free-floating pistons set in an air chamber mounted to the inside of the slide (fig. 5-6). Air pressure holds the pistons against the back of the housing, and forces them into the stationary chamber during recoil.

Since the air pressure in the counterrecoil system is the only thing holding the gun in battery, all guns are equipped with a **safety link**. The safety link physically attaches the housing to the slide to prevent it from moving if system pressure is lost. The safety link is disconnected prior to firing.

- **Firing Circuits**—Basically, a firing circuit supplies firing voltage to the propelling charge primer. This sounds simple, but the application can be quite complicated. Certain conditions must exist prior to firing to ensure a safe evolution. Ensuring that the gun is pointed in a safe direction, ensuring that all the loading equipment is in the fire position (out of the way of recoiling parts), and ensuring that the breechblock is all the way closed, are just a few of the obvious things that must be correct prior to firing. A typical electronic firing circuit includes inputs that monitor these and many other conditions, allowing firing voltage to pass only after all safety conditions have been satisfied.

- **Firing Cutouts**—A firing cutout mechanism interrupts firing when the gun is pointed at or near **permanent** ship's structure. A firing cutout is a mechanical device that monitors gun position. Firing cutouts were described in chapter 3.

The components we have just described are common to all guns. These same components apply equally to most missile launchers. Missile launchers will be discussed in chapter 7. We will now discuss the individual gun systems in the fleet today, paying particular attention to the loading system in each one.

GUN SYSTEMS

As you read this section and study the illustrations, note the different configurations of machinery designed to accomplish the same task from one gun to the next.

THE 3"/50 RAPID-FIRE (RF) GUN

The 3"/50 RF gun was planned during World War II to satisfy a need for a rapid-fire gun with a larger explosive projectile that could stop suicide planes and dive bombers. The 3"/50 mount was not finished in time to be used in combat during WW II, but it has been used extensively since then. It was produced in several versions including a single open, twin open, and twin enclosed mount.

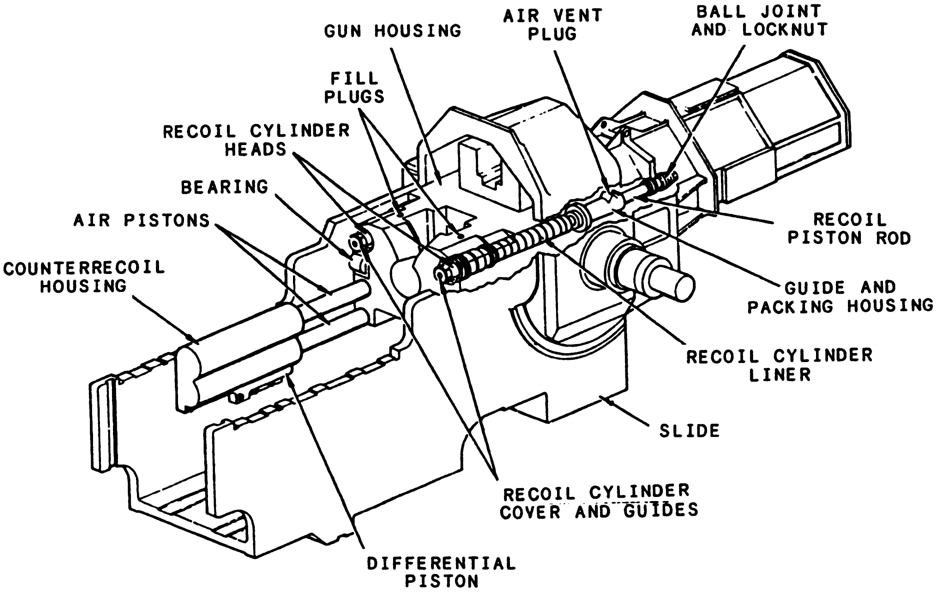

Figure 5-6.—5"/54 Mk 42 recoil and counterrecoil systems.

Although originally designed to function with the aid of a fire control system, all guns have since had the fire control system removed and now operate in local control only. At one time, virtually every ship in the fleet had one or more 3″/50 gun mounts. Today however, only amphibious warfare and auxiliary ships are still equipped with them.

Figure 5-7 shows the general layout of the 3″/50 gun mount and the manned stations on it during operation.

At the command of the mount captain, stationed between the guns, the mount can be controlled from two local positions. The **local surface** (right side) and the **local air** (left side) operator control mount movements can be

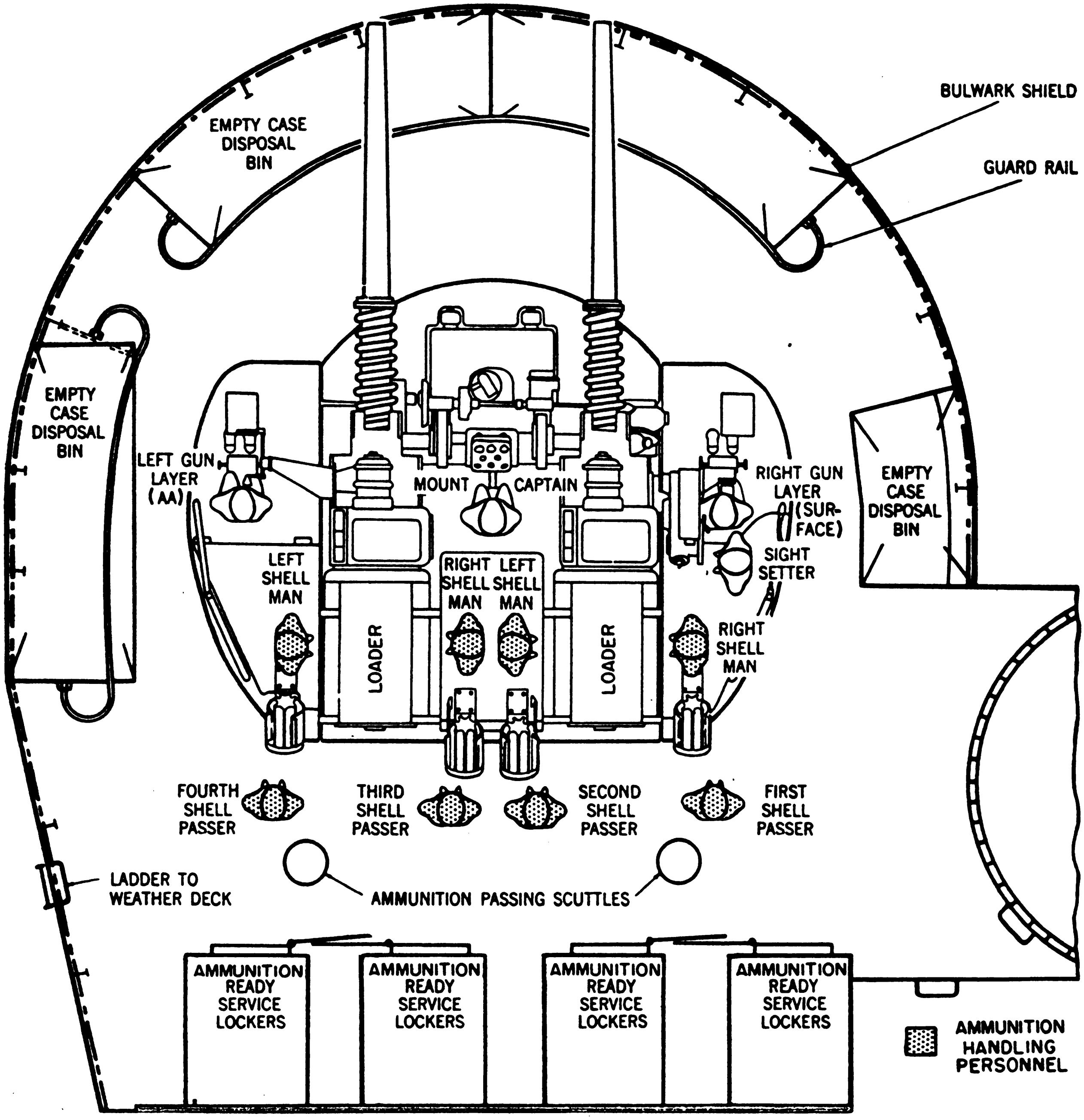

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Figure 5-7.—The 3″/50 gun mount manned positions.

accomplished using a **One-Man Control** (OMC) unit. The local surface operator uses an adjustable telescopic sight operated by the sight setter who stands behind him. The sight setter receives sight adjustment instructions from the mount captain who monitors the fall of shot. The local air operator uses a ring sight. The gun is fired from

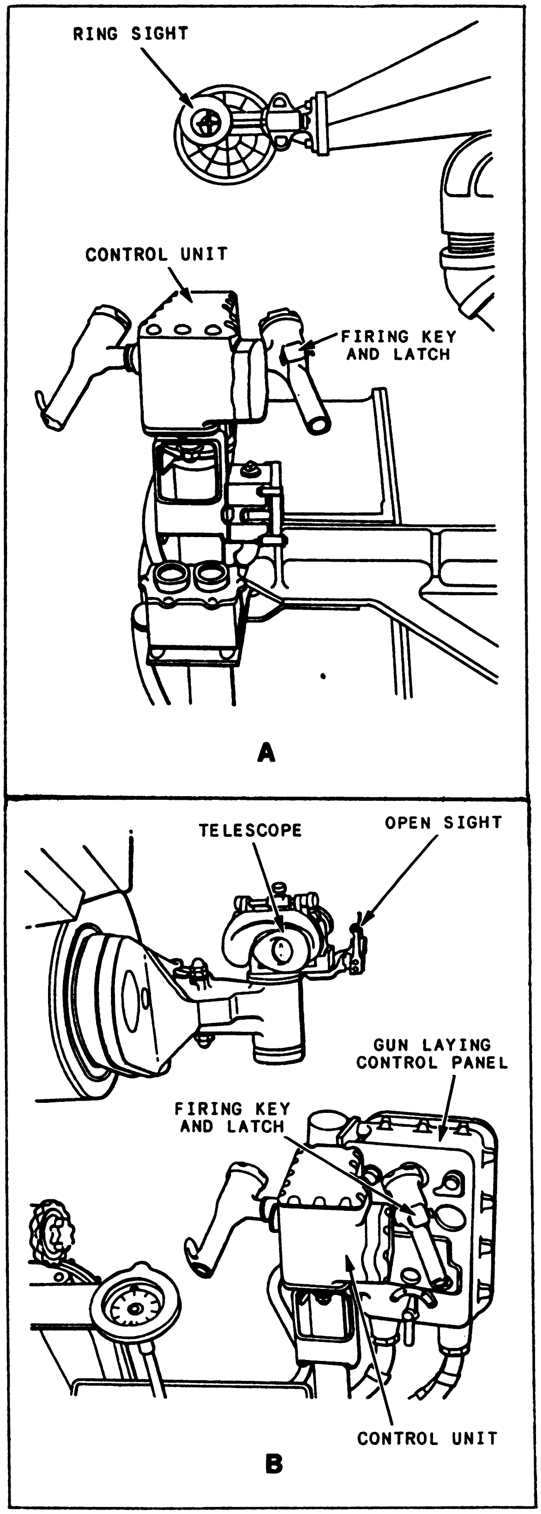

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Figure 5-8.—3"/50 mount. A. Local air station; B. Local surface station.

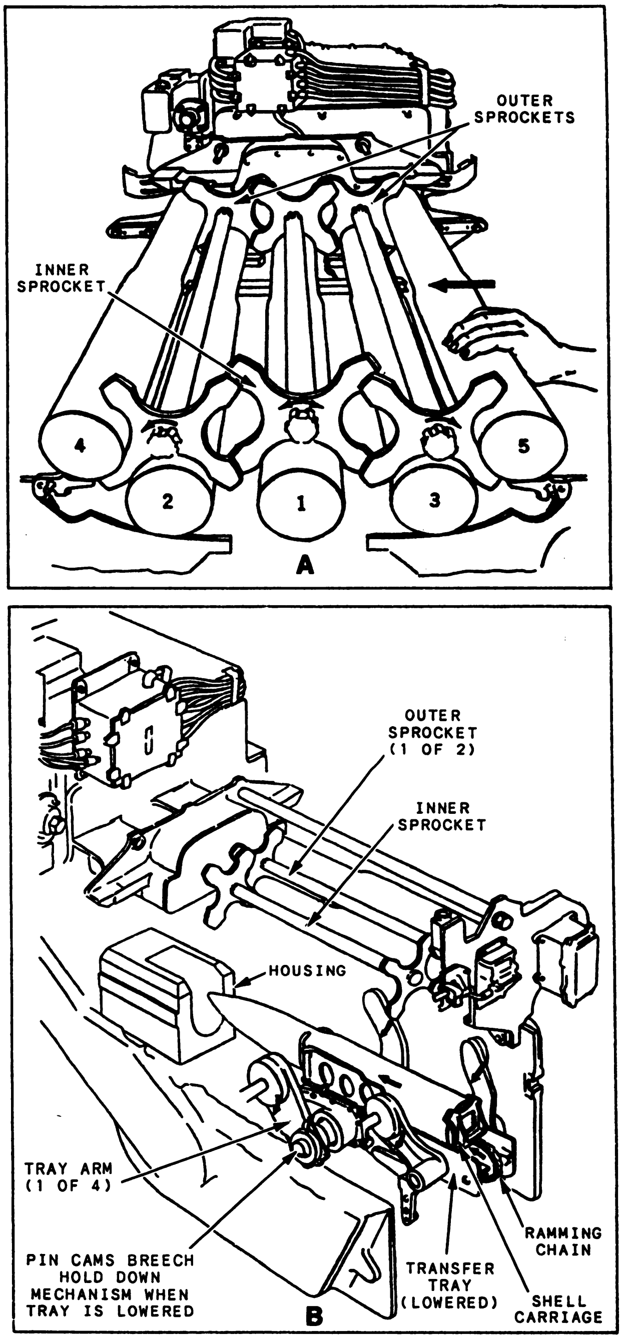

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Figure 5-9.—3"/50 loader. A. Sprockets being loaded (sprocket alternates direction of rotation each cycle); B. Cartridge being catapulted into breech.

the controlling position. Figure 5-8 illustrates the controls and sights at each station.

The 3″/50 gun uses a sprocket loader (fig. 5-9, view A) to index rounds into the transfer tray (fig. 5-9, view B) which pivots down to catapult the round into the breech. Depending upon the speed and accuracy (the mechanism is easily jammed) of the personnel loading the gun, a rate of fire up to 90 rounds per minute is possible.

THE 5″/38 GUN

The 5″/38 gun system had been the mainstay of naval gunnery since World War II, but it is now found only on battleships. Used primarily in conjunction with the Mk 37 GFCS, the 5″/38 has seen many years of service.

The 5-inch 38-caliber twin gun mount is a semiautomatic, dual-purpose mount, used as an antiaircraft and surface combat weapon. The mount can be controlled either automatically from a remote fire control system or locally from the mount handwheel stations. It fires an average 54-pound projectile to ranges up to 18,000 yards with a 37,300 foot ceiling. The guns are tray-loaded. This means that each round (powder then projectile) is hand-loaded into the gun tray, then rammed into the breech by the power rammer. The power rammer is activated by the projectile man after he lays the projectile in place. The rate of fire is determined by the speed of the individuals doing the loading. An average crew should be able to load 15 rounds per minute. Figure 5-10 illustrates a 5″/38 right-hand gun

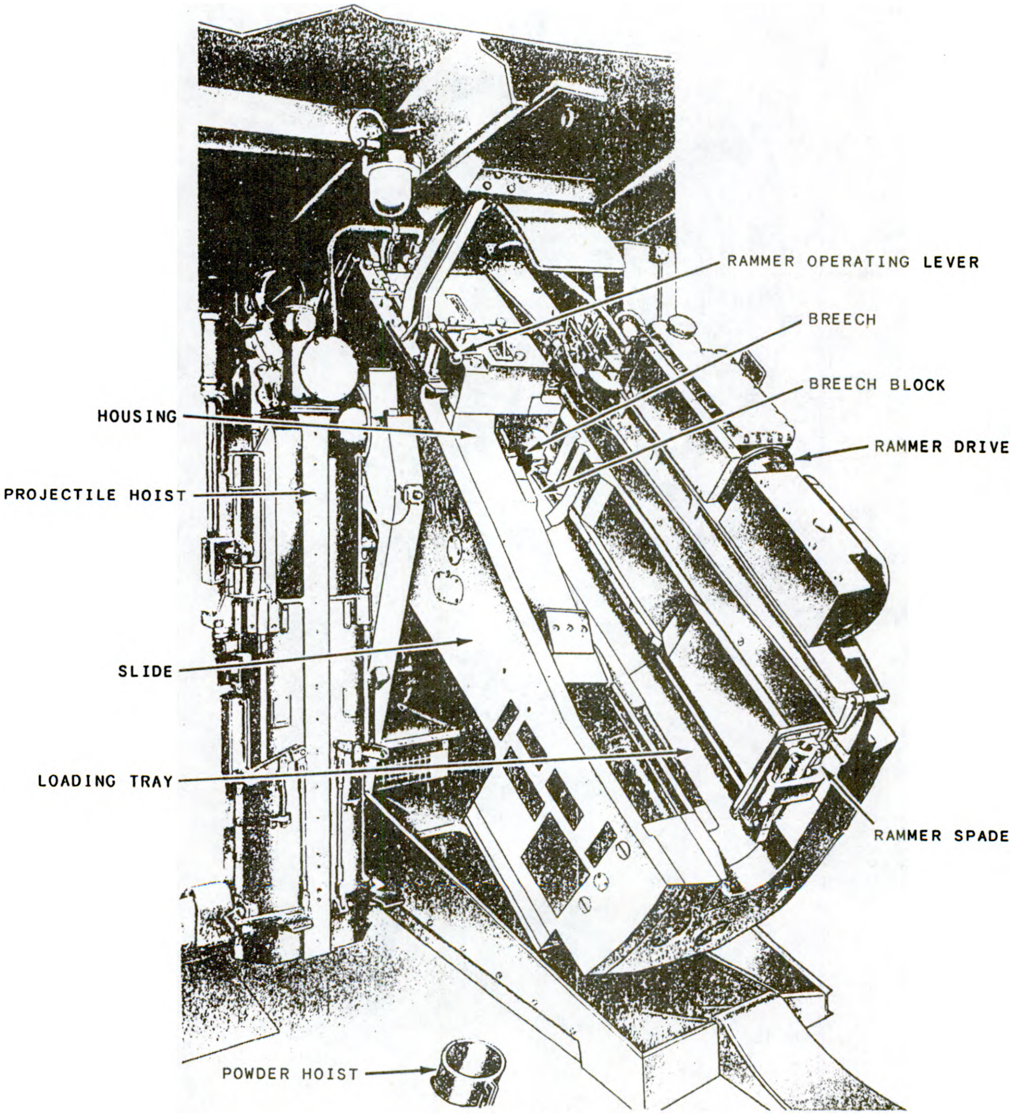

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Figure 5-10.—5″/38 right-hand gun assembly.

assembly and hoists. The hoists extend down to the handling room where they are hand-loaded by the handling room crew. The projectile mechanical time fuzes (MTFs) are continuously set while the projectile is in the hoist. The left-hand gun of a twin mount has its own powder and projectile hoists with the loading trays of both guns facing each other inboard.

When speaking of gun equipment, all directional nomenclature (left, right, front, back) is relative to the muzzle of the gun (the end of the barrel that the projectile exits when fired), which is to the front as you stand inside the gunhouse.

THE 5″/54 Mk 42 GUN

In the 1950s, as potential targets became faster and more sophisticated, a gun with more range and a faster rate of fire was needed. The 5″/54 Mk 42 was developed to effectively engage these targets as well as shore targets. Several versions of the Mk 42 gun have seen service since then. In the fleet today, you will find only the Mod 9 and the Mod 10; all others have been retired. The two versions are almost identical. The differences will be pointed out as we explain the systems.

The 5″/54 Mk 42, is an automatic, dual-purpose gun mount. It can be controlled either

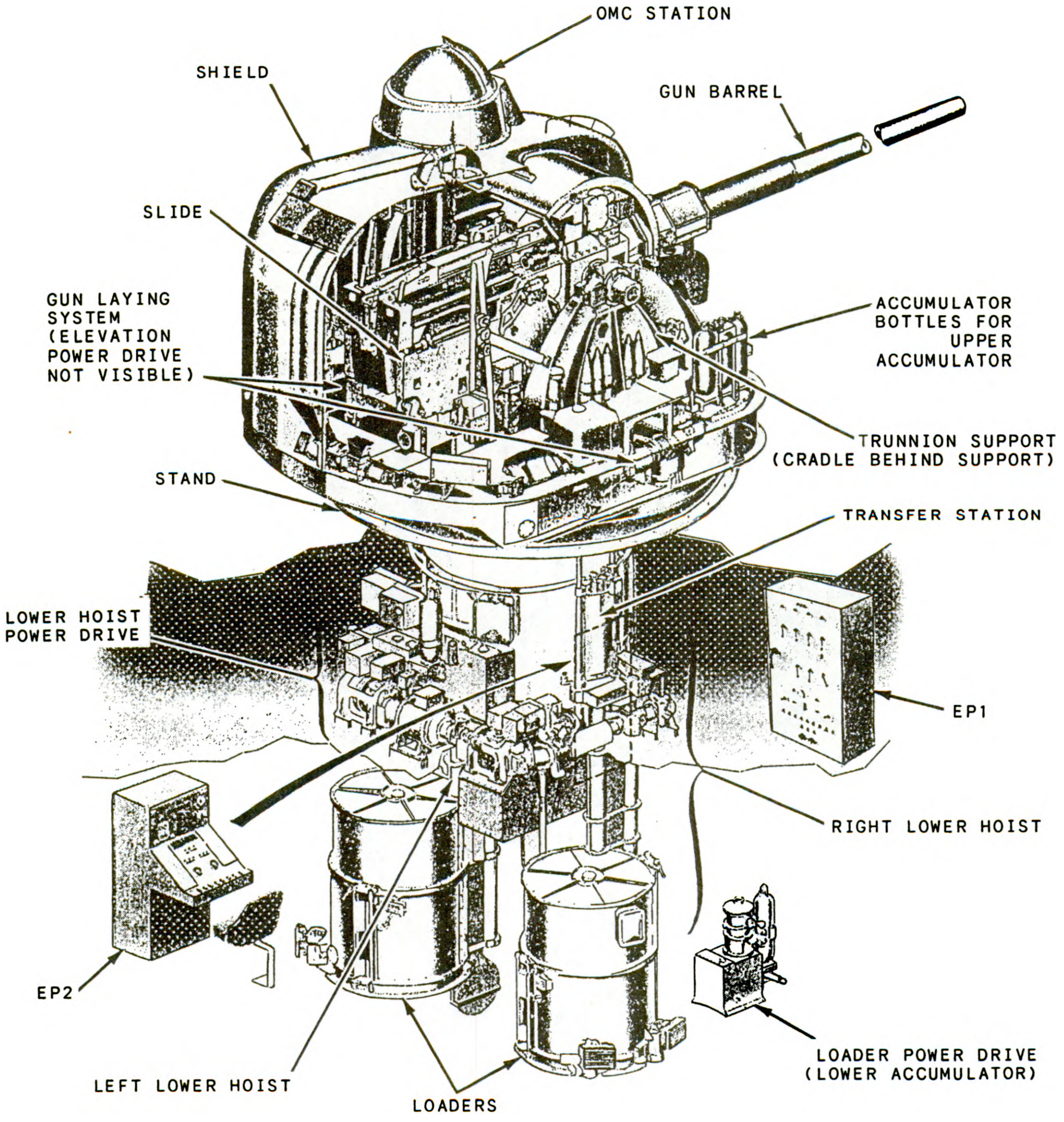
OMC STATION
SHIELD
GUN BARREL
SLIDE
GUN LAYING SYSTEM (ELEVATION POWER DRIVE NOT VISIBLE)
ACCUMULATOR BOTTLES FOR UPPER ACCUMULATOR
TRUNNION SUPPORT (CRADLE BEHIND SUPPORT)
STAND
TRANSFER STATION
LOWER HOIST POWER DRIVE
EP1
RIGHT LOWER HOIST
EP2
LOADER POWER DRIVE (LOWER ACCUMULATOR)
LEFT LOWER HOIST
LOADERS

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Figure 5-11.—Major components of the 5″/54 Mk 42 (Mod 10 shown).

remotely from a fire control system, usually the Mk 68 GFCS, or locally from the mount at the One Man Control (OMC) station. The normal mode of operation is the remote mode. The mount fires an average 70-pound projectile up to 26,000 yards with a 48,000 foot ceiling. The gun, with its automatic loading system, has a rate of fire of 34 rounds per minute.

As you will see, the loading system is actually two almost separate systems, left and right. The ammunition carrier (described later) and the hydraulic power drive units are the only components shared by both sides. The advantage of having separate systems is readily apparent. In the event of a casualty, you can isolate the affected side and continue to fire at 17 rounds per minute from the other side.

We will now describe the major components of the mount as we walk through a loading cycle.

Crew Positions and Responsibilities

Figure 5-11 illustrates the major components that make up the 5″/54 Mk 42 gun. The gun is operated by the **mount captain** from the **EP2** panel. Electrical power is supplied to the gun through the **EP1** panel. Both the EP1 and EP2 panels are located in the compartment directly under the mount, along with the **lower hoist** power drive, **ammunition carrier,** and **upper hoists.** This compartment is commonly called the **carrier room.** Inside the gun mount, there are two manned positions—the **gun captain** and the **OMC** operator. The gun captain has the responsibility of monitoring the operation of the gun and relaying **bore reports** (whether or not the gun bore is clear) after each round or salvo is fired. The OMC operator functions as a **check sight observer** during normal firing. As check sight observer, he uses the telescopic sight to ensure that the gun is trained on the intended target. He then reports "CHECK SIGHT ON TARGET." The loader drums, located in the projectile magazine, are served by the magazine crew.

When a remote order is received, the mount captain gives control of gun train, elevation, and firing circuit to the fire control system. When ordered to fire, he initiates the loading cycle by pressing the **RAM ONCE** or the **RAM CONTINUOUS** button on the EP2 panel. RAM ONCE allows one round to be loaded and fired. RAM CONTINUOUS allows the gun to continue firing until it is empty or ordered to stop by the mount captain, who presses the **OFF** button. In both instances, the rounds are fired using firing voltage supplied from the fire control system. When firing is controlled from the OMC station, the operator supplies all the inputs normally received from the fire control system. He positions the mount with the OMC unit, while aiming with the telescopic sight. He then fires the gun using his own firing key. Note that the mount captain has to physically give control of the mount to the intended operator.

Loading Sequence

Now let's look at a load and fire sequence of the Mk 42 Mod 10 gun mount. Suppose the gun is in remote, the loader drums are full, and the mount captain has just pressed the button that will cause the system to load itself to the top in preparation for firing. We have identified and illustrated 24 gun-loading sequence steps for clarification.

With the loaders fully loaded, rounds 1 and 2 are at the hoist position (fig. 5-12). A lift pawl on each hoist chain is beneath each round. The lower hoists now raise rounds 1 and 2 to the first

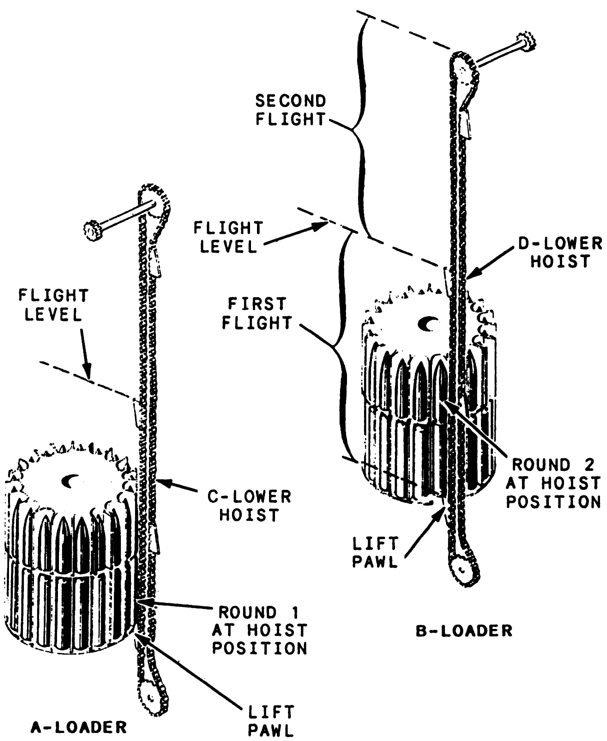

Figure 5-12.—Gun loading sequence—Step 1.

flight level (fig. 5-13). When rounds 1 and 2 are clear of the loader drums, the loader's index rounds 3 and 4 to the hoist position where another lift pawl is positioned under the powder case (fig. 5-14). The lower hoist continues to raise rounds 1 and 2 toward the transfer stations (fig. 5-15) and rounds 3 and 4 toward the first flight level. When rounds 3 and 4 are clear of the loader drums, the loaders index rounds 5 and 6 over another set of lift pawls. Rounds 1 and 2 seat on transfer level pawls in the transfer stations (fig. 5-16) as the lift pawl continues over the top of the upper sprocket. The transfer station ejectors then eject rounds 1 and 2 into the ammunition carrier (fig. 5-17).

Once in the ammunition carrier, rounds 1 and 2 are no longer in the stationary lower gun loading system. The ammunition carrier bridges the gap between the stationary lower loading system and the movable upper loading system. As rounds 1 and 2 continue through the system from one position to another, the system continually fills each vacant slot in a similar fashion.

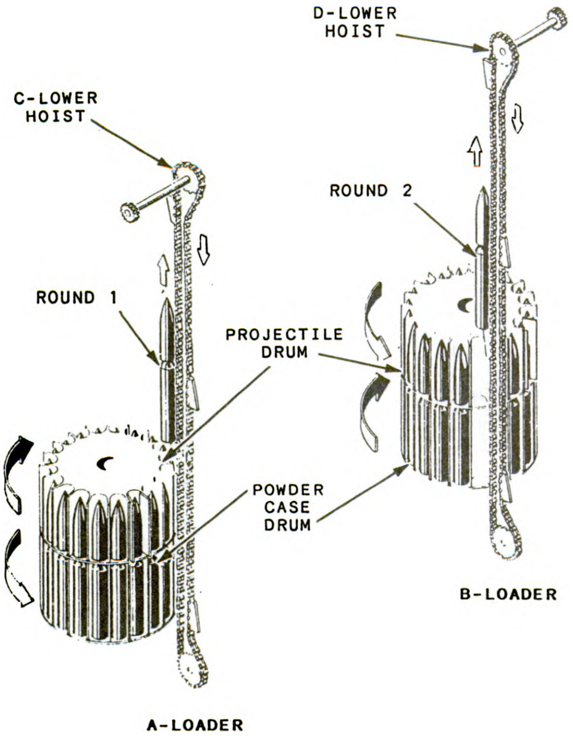

Figure 5-13.—Gun loading sequence—Step 2.

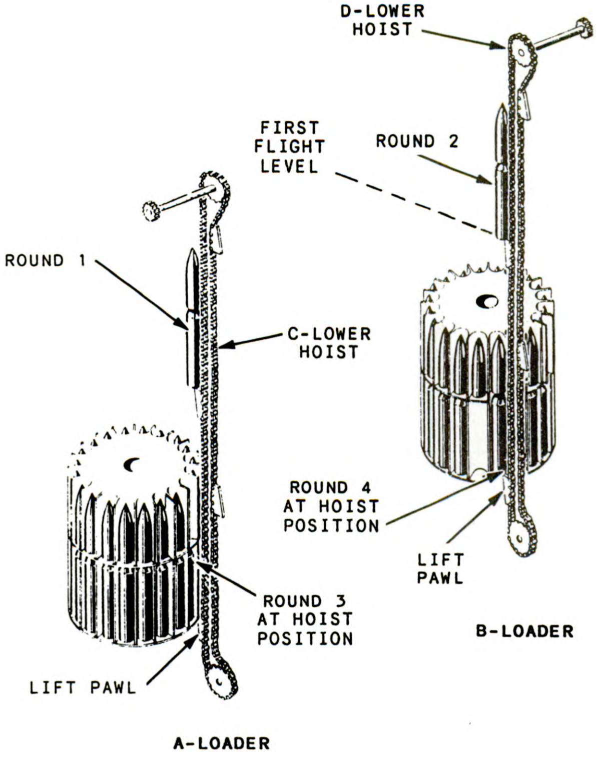

Figure 5-14.—Gun loading sequence—Step 3.

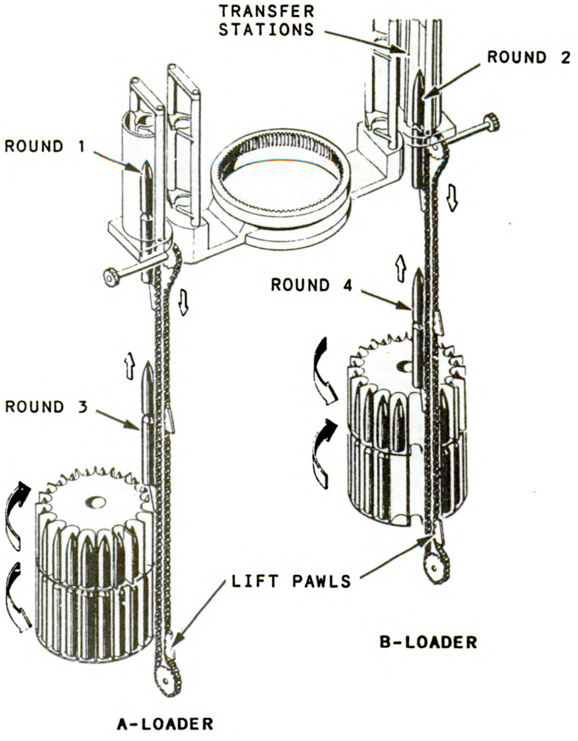

Figure 5-15.—Gun loading sequence—Step 4.

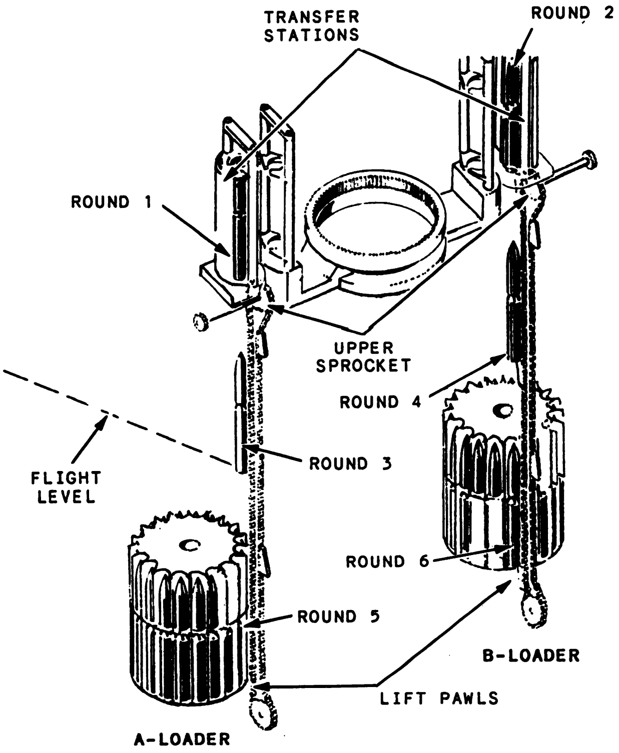

Figure 5-16.—Gun loading sequence—Step 5.

The ammunition carrier then unlatches from the lower hoists and rotates to the upper hoists (fig. 5-18). As the ammunition carrier rotates to the upper hoists, the lower hoists cycle, raising rounds 3 and 4 to the transfer stations (fig. 5-19)

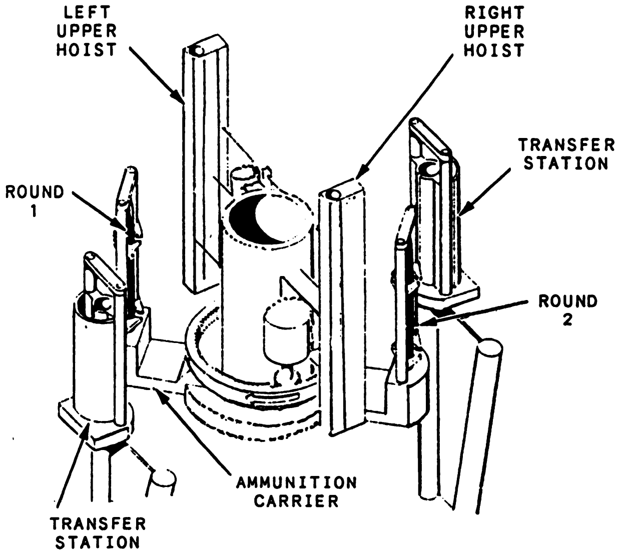

Figure 5-18.—Gun loading sequence—Step 7.

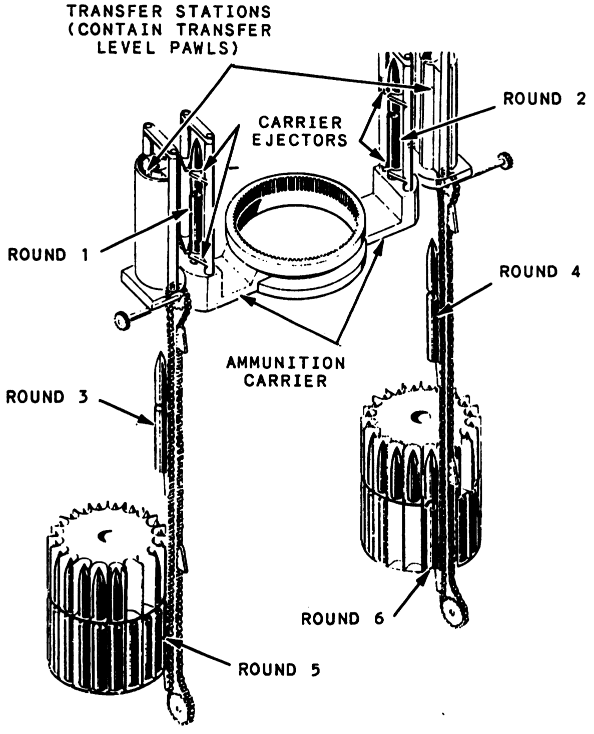

Figure 5-17.—Gun loading sequence—Step 6.

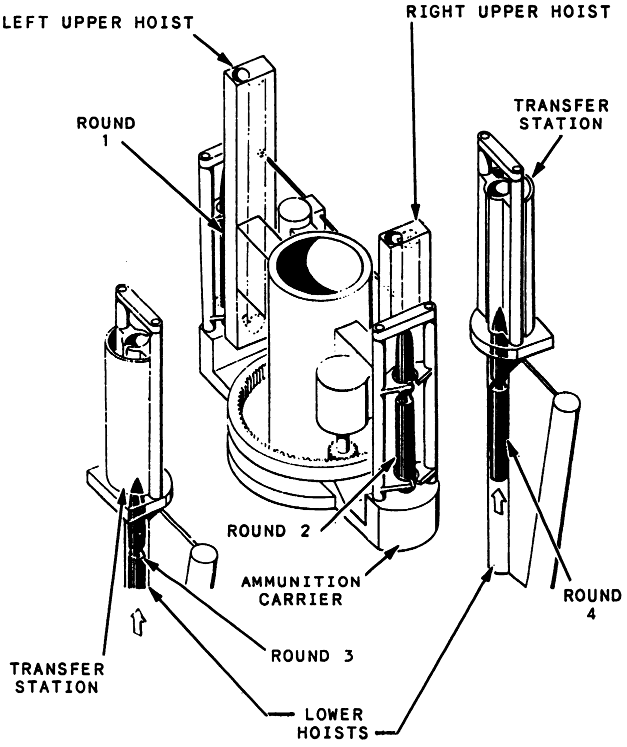

Figure 5-19.—Gun loading sequence—Step 8.

and rounds 5 and 6 to the flight level position. The ammunition carrier aligns with the upper hoists and ejects rounds 1 and 2 into them (fig. 5-20), then returns to the lower hoists. The upper hoists raise, first one round then the other, placing them in the left and right cradles.

Round one is raised first into the left cradle (fig. 5-21) where it is secured (fig. 5-22). The left cradle unlatches from the upper hoist and raises to latch to the slide along side the left transfer tray (fig. 5-23). The right-upper hoist now raises round 2 into the right cradle (fig. 5-24).

The left cradle now ejects round 1 into the left transfer tray (fig. 5-25). The transfer tray clamps and shutters close securing the round (fig. 5-26) and the fuze setter extends (if an MT fuze is used). The left cradle then unlatches, pivots, and latches at the left-upper hoist. At the same time, the right cradle unlatches from the right-upper hoist, pivots,

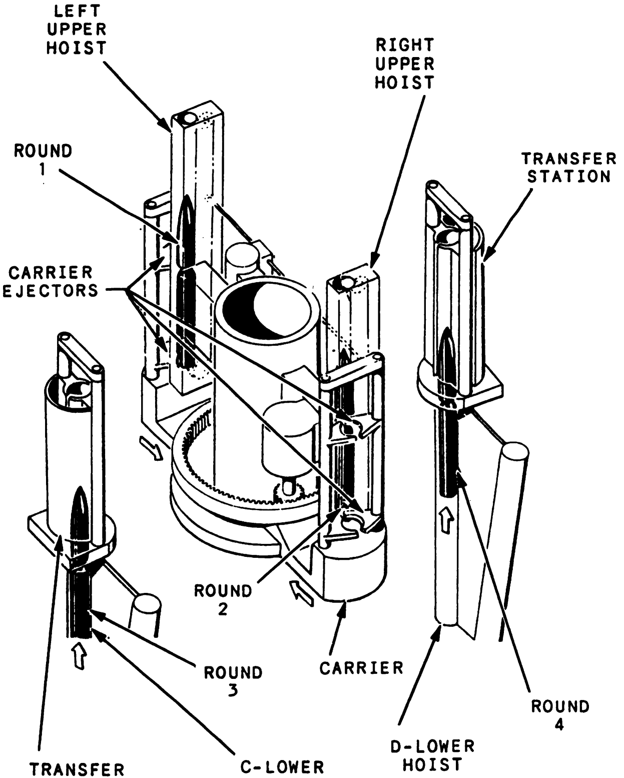

Figure 5-20.—Gun loading sequence—Step 9.

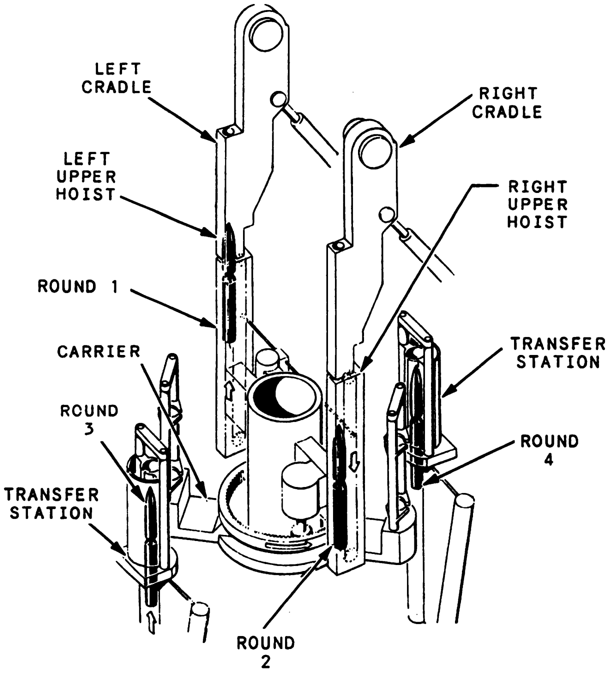

Figure 5-21.—Gun loading sequence—Step 10.

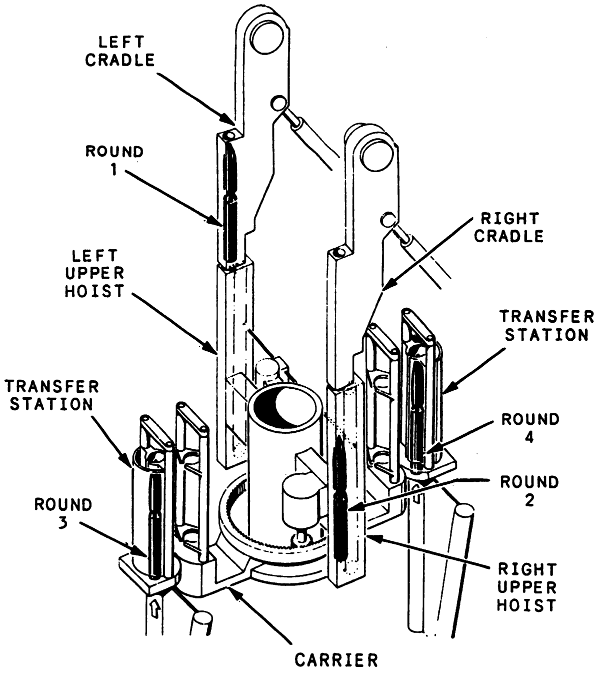

Figure 5-22.—Gun loading sequence—Step 11.

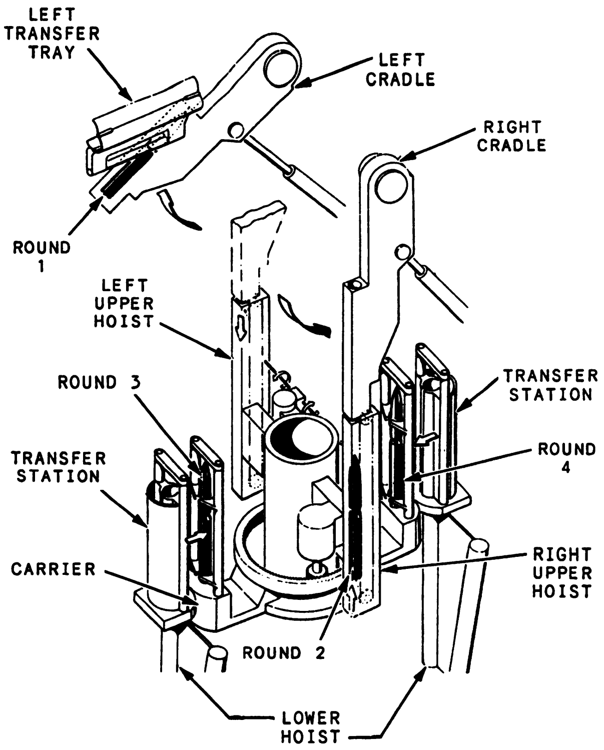

Figure 5-23.—Gun loading sequence—Step 12.

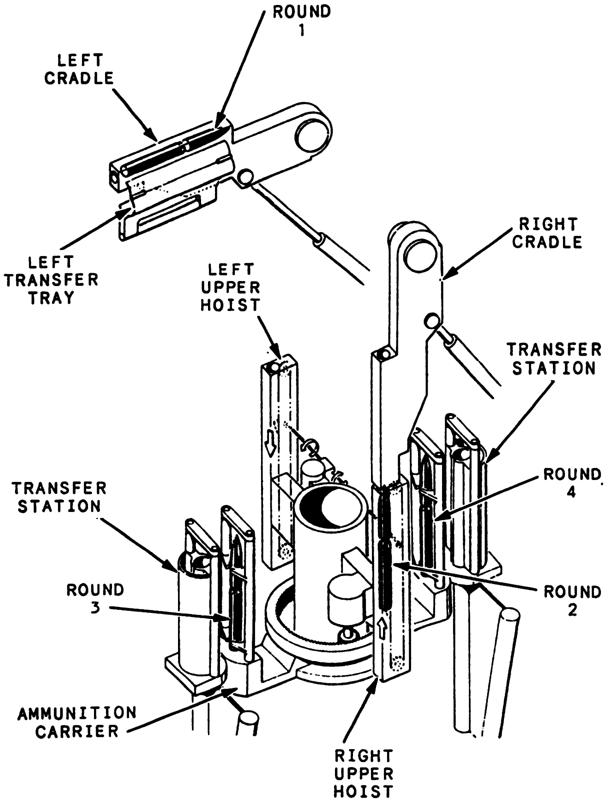

Figure 5-24.—Gun loading sequence—Step 13.

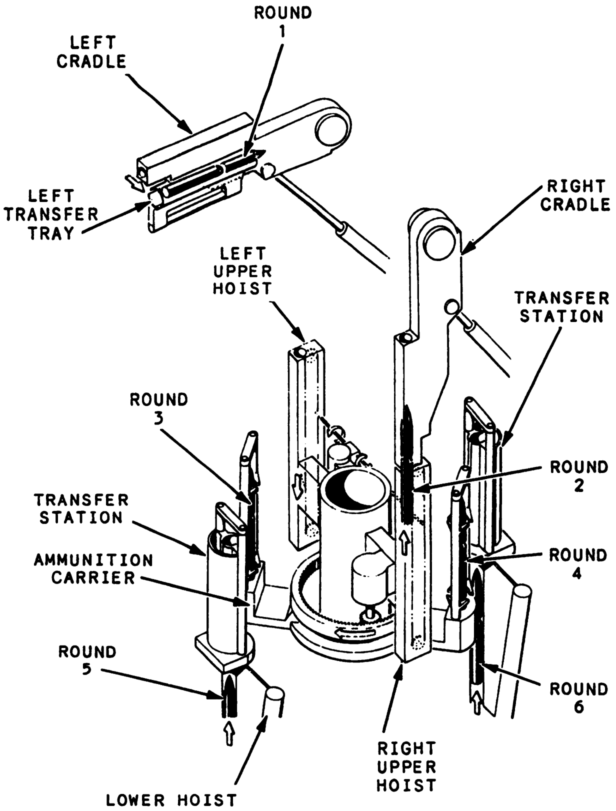

Figure 5-25.—Gun loading sequence—Step 14.

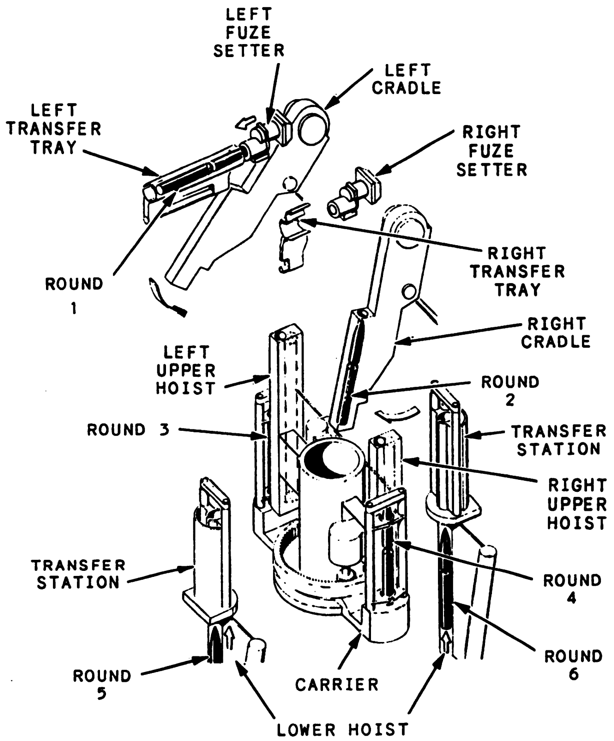

Figure 5-26.—Gun loading sequence—Step 15.

and latches to the slide next to the right transfer tray (fig. 5-27).

The gun is now ready to commence a firing cycle on command. When the fuze is set on round 1 and the firing key is closed, the left fuze setter retracts and the left transfer tray (fig. 5-28) lowers the round into the ram position. The right cradle, at the same time, ejects round 2 into the right transfer tray. As the left transfer tray lowers, the clamps open to free the round for ramming. When round 1 is in position, the rammer spade moves forward, contacting the base of the powder, ramming it and the projectile into the breech (fig. 5-29). With round 1 in the breech, the breechblock closes (fig. 5-30), the left transfer tray and empty case tray raise to the fire position (transfer tray clear of recoiling parts and empty case tray in position to receive the empty powder case).

When the gun fires and recoils (fig. 5-31), the rammer retracts, the breech opens (breechblock lowers), and the empty case extractors start to extract the empty case from the breech into the empty case tray. As the gun moves back into battery (counterrecoil), the gas ejector clears the gases from the gun breech and bore.

When the fuze is set on round 2 and the firing key is closed, the right fuze setter retracts, allowing the right transfer tray to lower into the ram position and the empty case tray to lower to the eject position (fig. 5-32). With the right transfer tray in the ram position and the empty case tray in the eject position (fig. 5-33), the

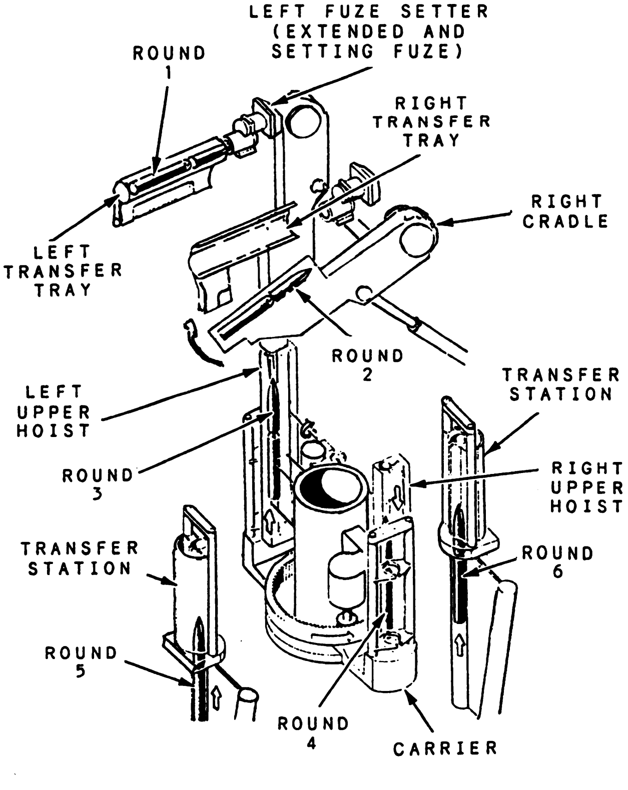

Figure 5-27.—Gun loading sequence—Step 16.

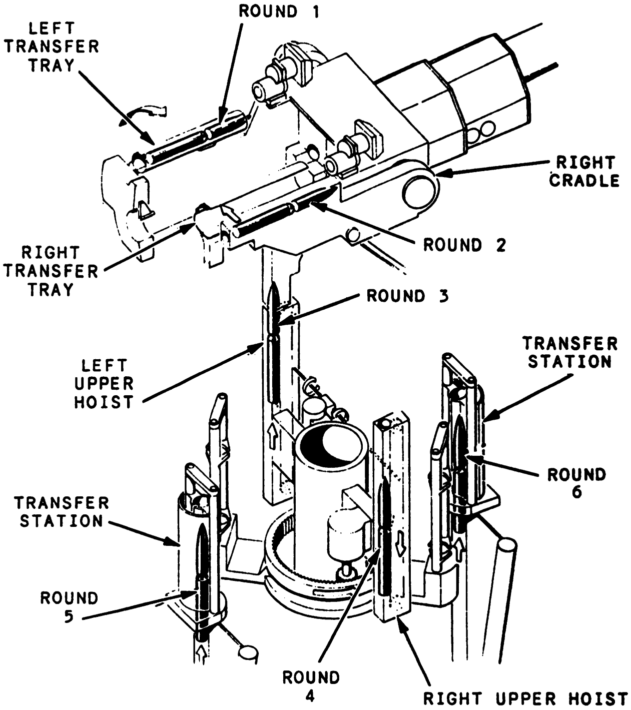

Figure 5-28.—Gun loading sequence—Step 17.

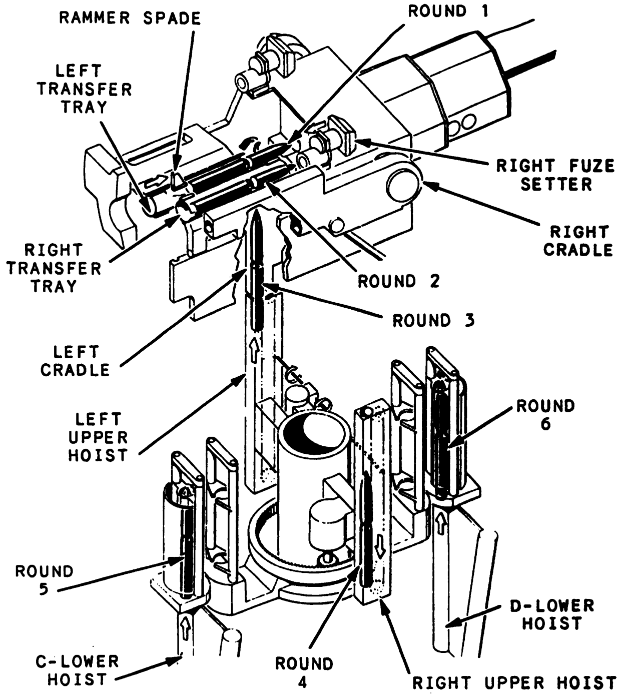

Figure 5-29.—Gun loading sequence—Step 18.

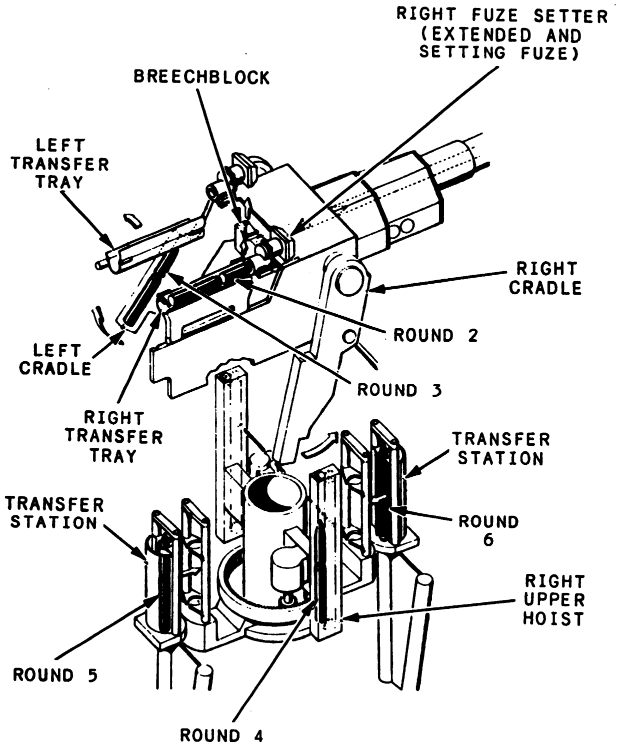

Figure 5-30.—Gun loading sequence—Step 19.

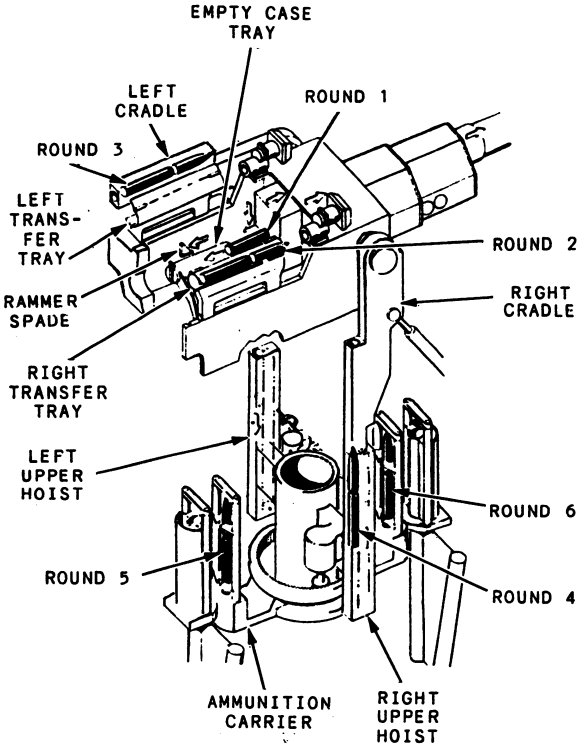

Figure 5-31.—Gun loading sequence—Step 20.

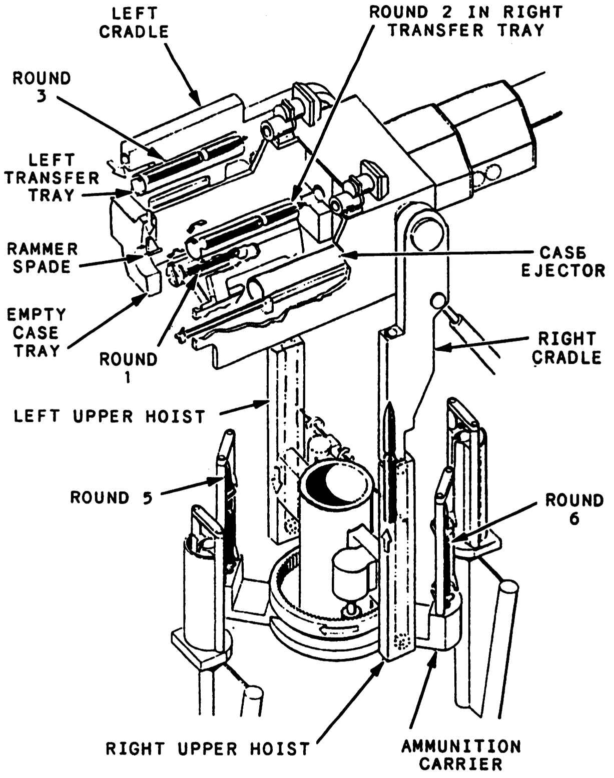

Figure 5-32.—Gun loading sequence—Step 21.

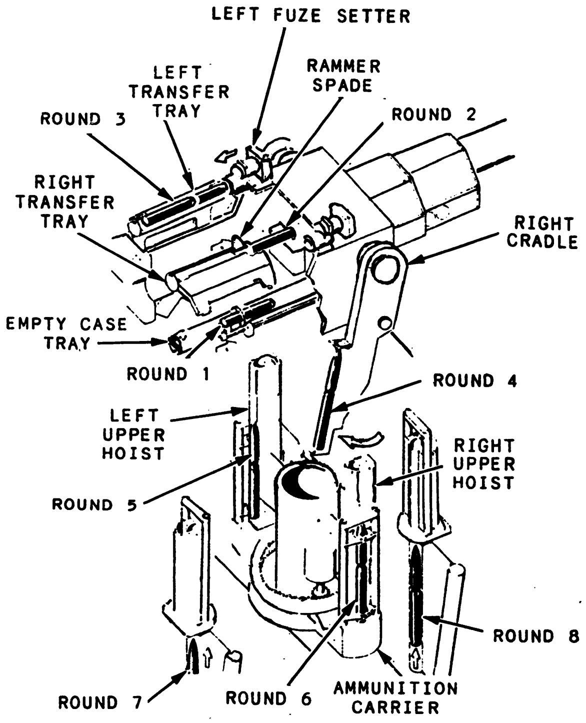

Figure 5-33.—Gun loading sequence—Step 22.

rammer spade contacts the base of the powder case ramming it into the breech, while the empty case ejector moves the empty case into the empty case ejector tube.

With round 2 rammed into the breech and the breechblock raised, and the right transfer tray and empty case tray raised to the fire position, the gun fires (approximately 1.45 seconds after round 1) and recoils (fig. 5-34). With the firing key still closed, the left transfer tray lowers to ram round 3 and eject round 2 (fig. 5-35). Additional rounds are fired in the same manner.

When the empty case of the final round is extracted into the empty case tray, a special circuit called "kick the can" lowers the empty transfer tray and cycles the empty case ejector three times to remove any remaining empty cases.

The Mk 42 Mod 9 is identical to what we just described with only a few exceptions. The most notable exception is that the Mod 9 does not have transfer stations, the lower hoists feed directly into the carrier. The Mod 9 also does not have a lower accumulator drive unit, but drives both the loader drums and the lower hoists off the lower hoist drive unit. The Mod 9 also uses a Mk 29 fuze setter instead of the Mk 27 fuze setter used on the Mod 10 gun.

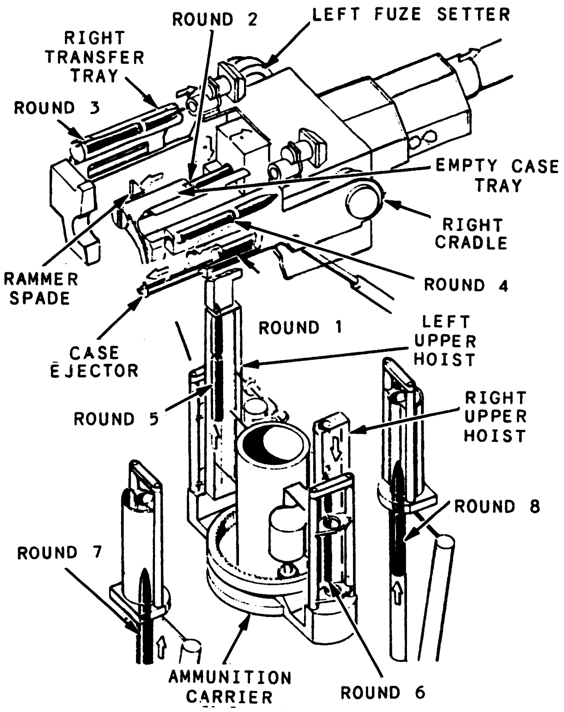

Figure 5-34.—Gun loading sequence—Step 23.

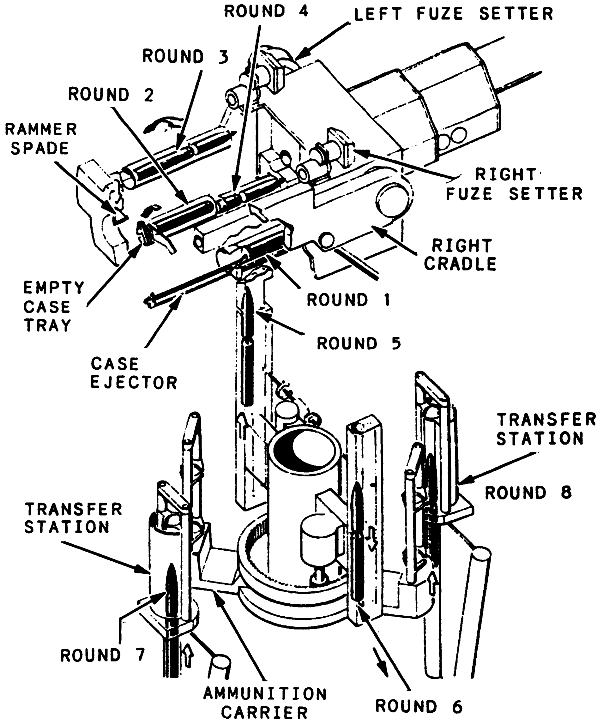

Figure 5-35.—Gun loading sequence—Step 24.

What we just described in actuality takes only seconds to happen. As you can see, a modern gun system is very sophisticated. Many of the mechanisms shown here on the Mk 42 have very similar counterparts on the newer guns we are about to explain.

THE 5"/54 MK 45 GUN

The 5"/54 Mk 45 gun, developed in the early 1970s, is the newest of the 5" guns in the fleet today. It is found aboard the DD-963, DDG-51, LHA-1, and CG-47 class ships with the Mk 86 GFCS. The Mk 45 gun is currently found in two versions, the Mod 0 and the Mod 1, with Mods 2 and 3 currently under development. The major differences between the two is that the Mod 1 is designed to fire guided projectiles and has electronic upgrades in its control circuits. These will not be covered in this text since the main components of the loading system are the same.

The Mk 45 (fig. 5-36) is a fully automatic, dual-purpose, light weight gun mount capable of firing the full range of 5"/54 projectiles, including RAP (rocket assisted projectiles) at a rate of 17 to 20 rounds per minute. During normal operation

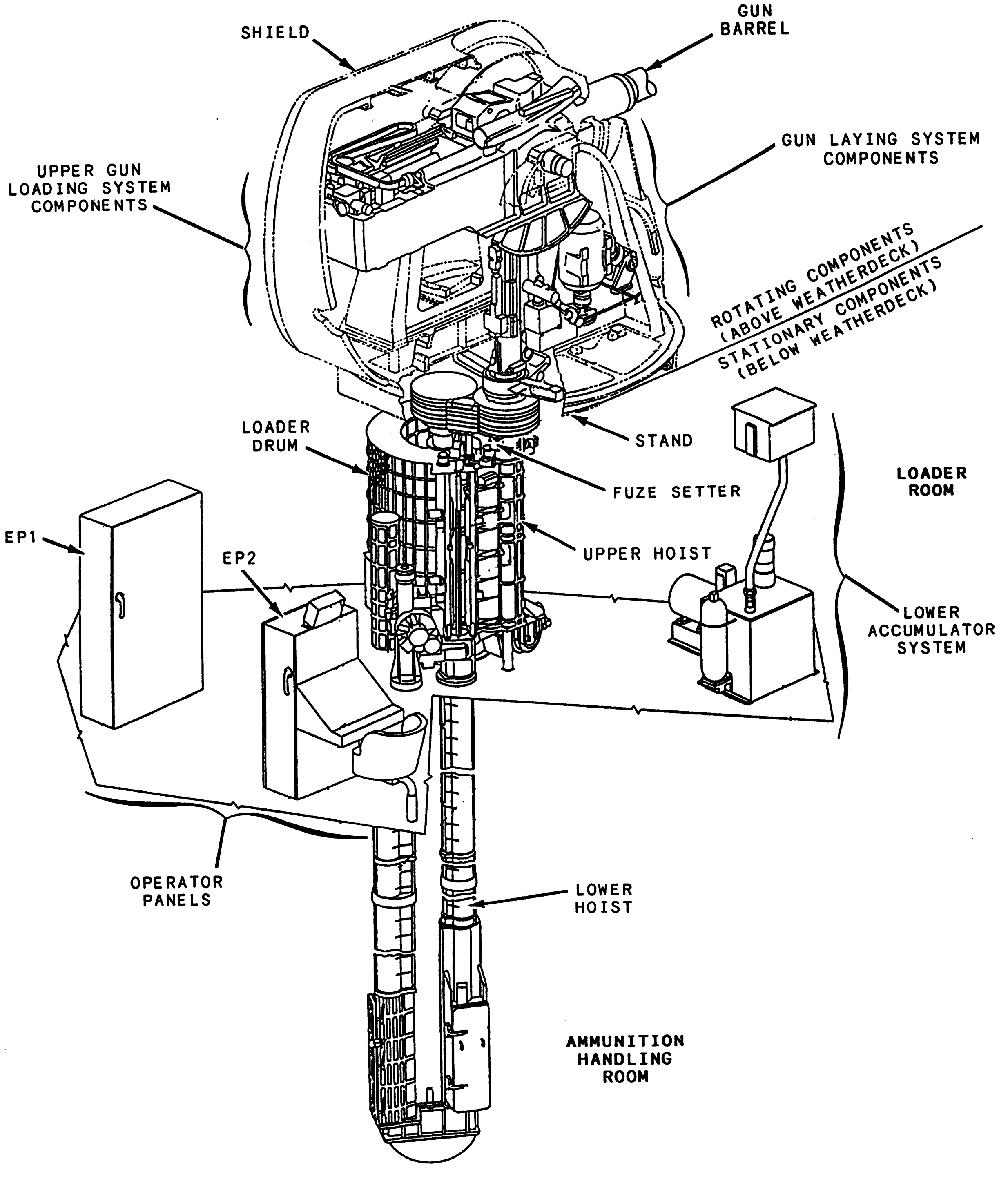

Figure 5-36.—The 5"/54 Mk 45 Mod 0, general arrangement.

the loading system (fig. 5-37), like the Mk 42, is operated locally by the mount captain while gun laying, fuze setting, and firing orders are generated by the FCS. The gun may be positioned locally from the EP2 panel for maintenance purposes only.

Crew Positions and Responsibilities

The only manned positions on the Mk 45 gun during normal operations is the mount captain who operates the gun from the EP2 panel and the loader room crew. The gun mount itself, unlike the Mk 42, is unmanned. There is no local firing position as with the Mk 42 OMC. The mount power distribution panel, EP1, is also the mount captain's responsibility.

The loader drum holds a total of 20 complete rounds of ammunition. Prior to an operation, the loader crew will load the drum, through the lower hoist, with 20 rounds of one type of ammunition. If during the operation another type of round is

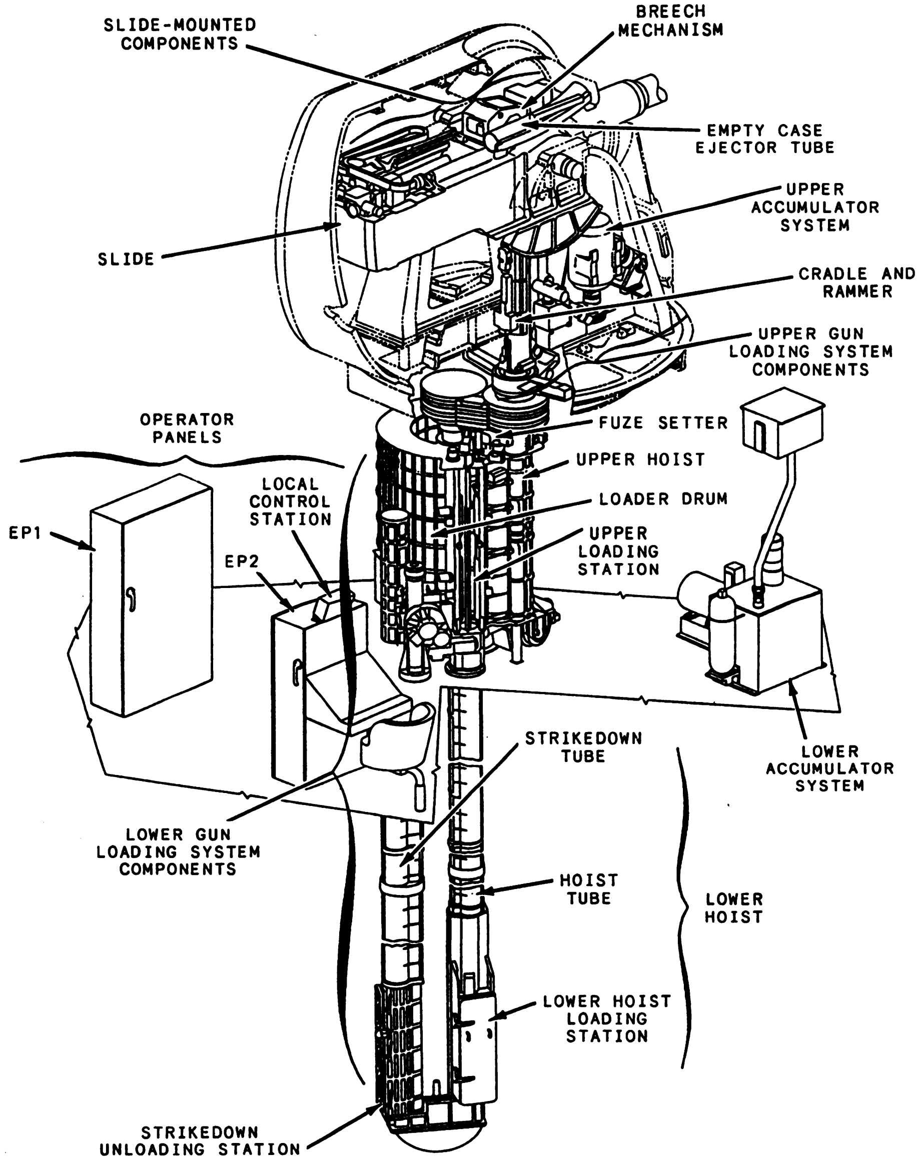

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Figure 5-37.—The 5"/54 Mk 45 gun loading system; major components.

desired, the mount captain, using local controls, can allow the system to operate under **alternate loading**. This mode allows the loaders to hand-feed the different types of ammunition into the loading system, which automatically transfers only these rounds to the breech for firing.

Loading Sequence

Usually at the start of a load-and-fire operation, the **rotating drum** already has a compliment of ready-service ammunition (all the same type). If not, the ammunition handlers immediately begin hand-feeding powder cases and projectiles into the loading system at the **lower hoist** (fig. 5-38). The lower hoist then raises the rounds to the **upper loading station,** where the **ejector** transfers the rounds into the rotating drum.

With a load-and-fire order in effect, the rotating drum indexes until a loaded cell reaches the **transfer station**. At the transfer station, a positioning mechanism aligns the round

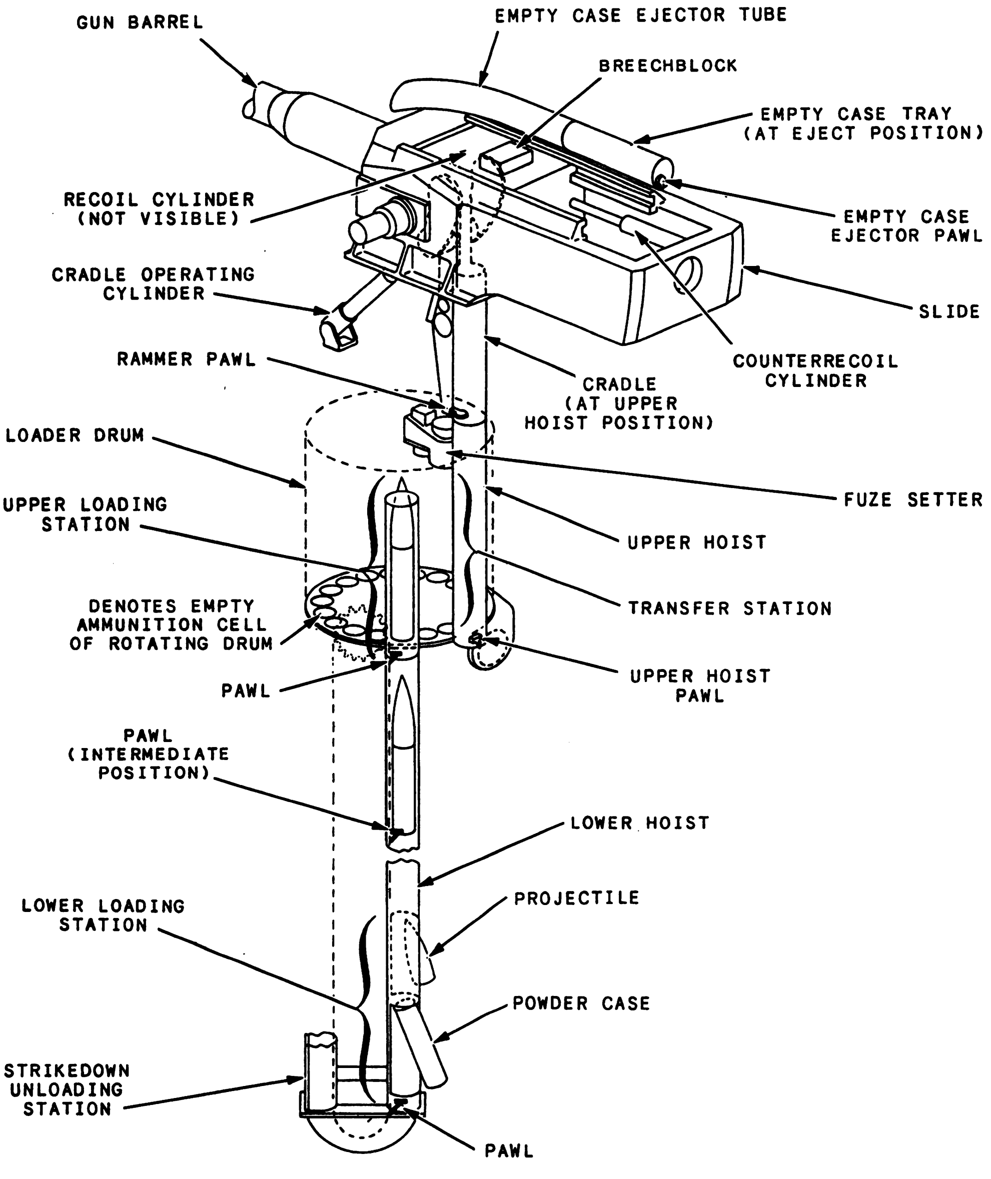

Figure 5-38.—Filling of loader drum through the lower hoist.

to the **fuze setter** mounted overhead. If the projectile has an MT fuze, the fuze setter extends (fig. 5-39), sets the fuze, and retracts. An **ejector** then transfers the round into the **upper hoist** (fig. 5-40).

With the first round in the upper hoist and the hoist raising, the rotating drum indexes clockwise to bring the next loaded cell into place. The upper hoist raises the first round into the **cradle** (fig. 5-41), which is latched

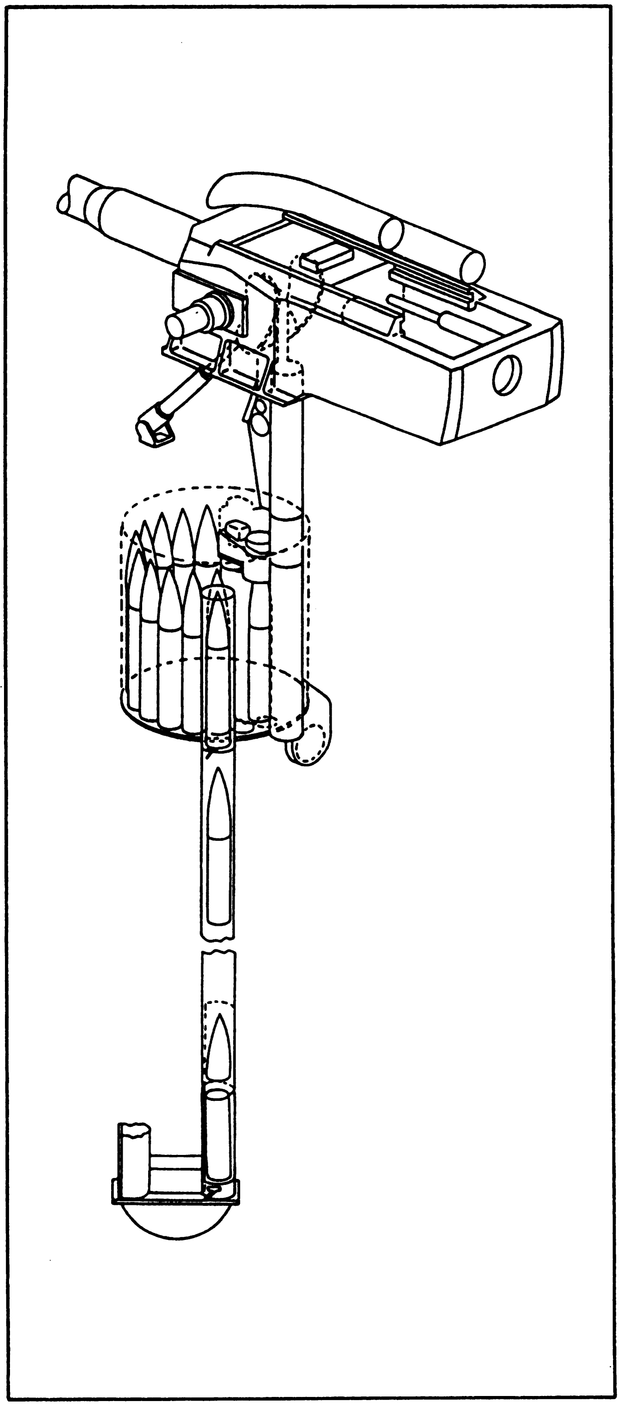

Figure 5-39.—A round at the transfer station with fuze setter in place setting fuze.

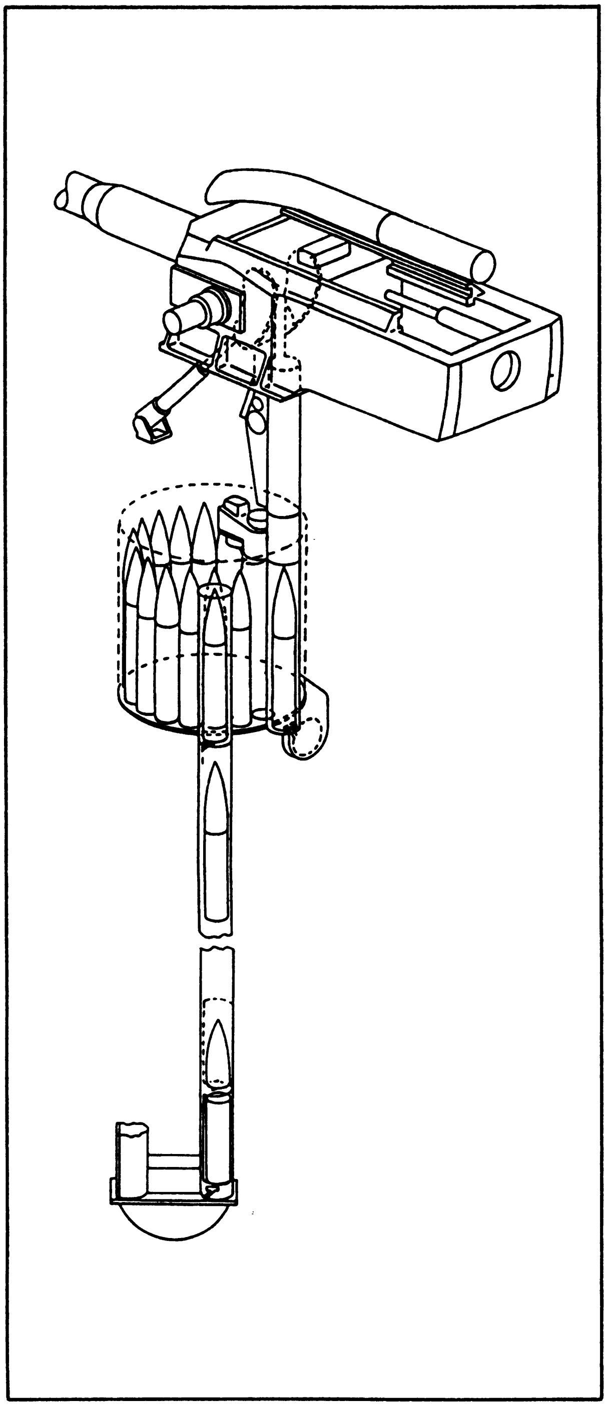

Figure 5-40.—First round in the upper hoist.

at the hoist position. The **cradle pawl** holds the round while the hoist pawl lowers for the second round. When the hoist pawl is clear of the cradle, the cradle unlatches and pivots upward (raises) to align with the gun bore (fig. 5-42).

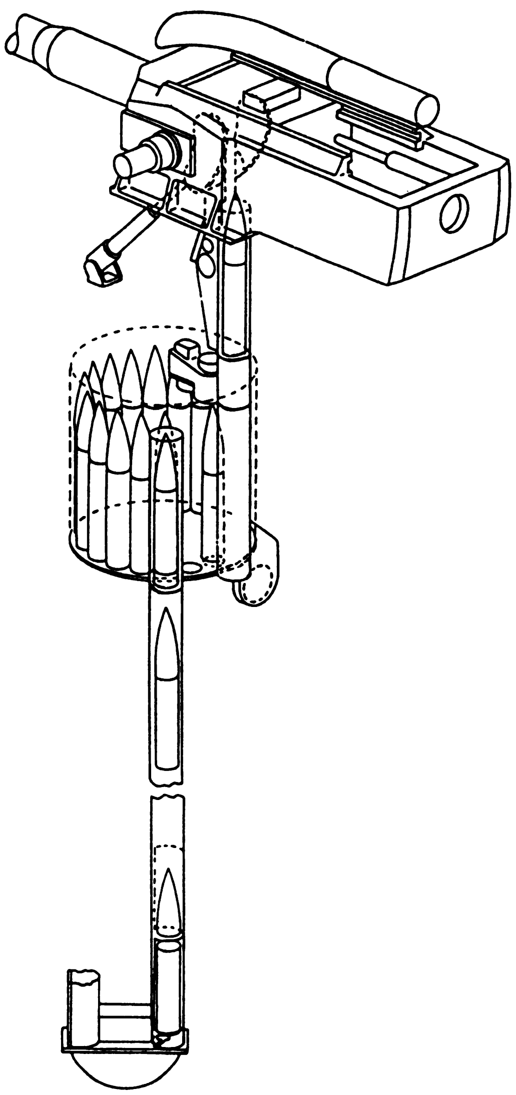

Figure 5-41.—First round raised into the cradle.

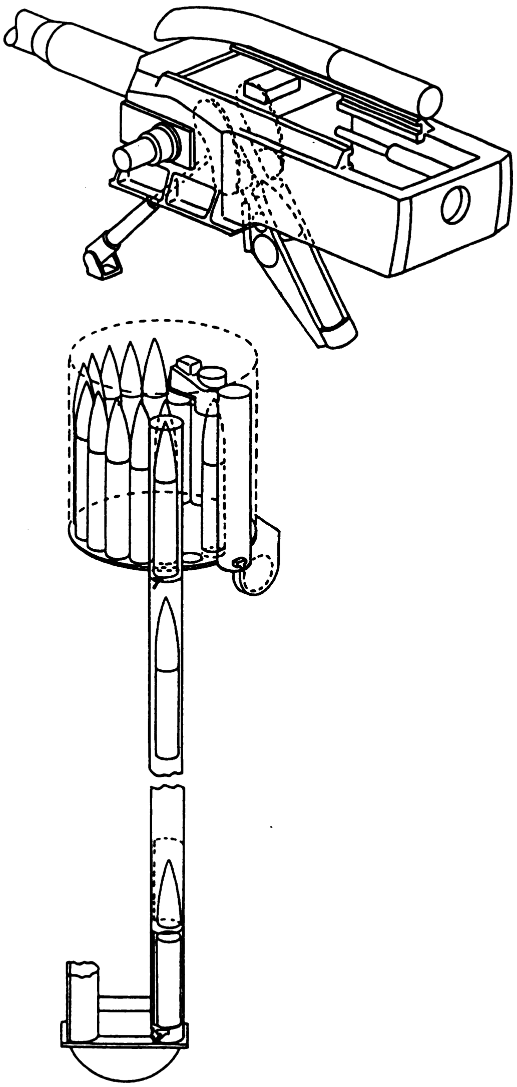

Figure 5-42.—The cradle raises.

The cradle completes the raise cycle and latches to the slide (fig. 5-43). The **rammer** extends, driving the round into the breech. At this time the **breechblock** partially lowers (closes) to hold the round in the breech, while the cradle lowers to receive another round.

While the cradle is still raised, after the round has been rammed, the rammer retracts, and another round is ejected into the upper hoist (fig. 5-44).

With the rammer retracted, the cradle lowers, the breechblock closes completely, and

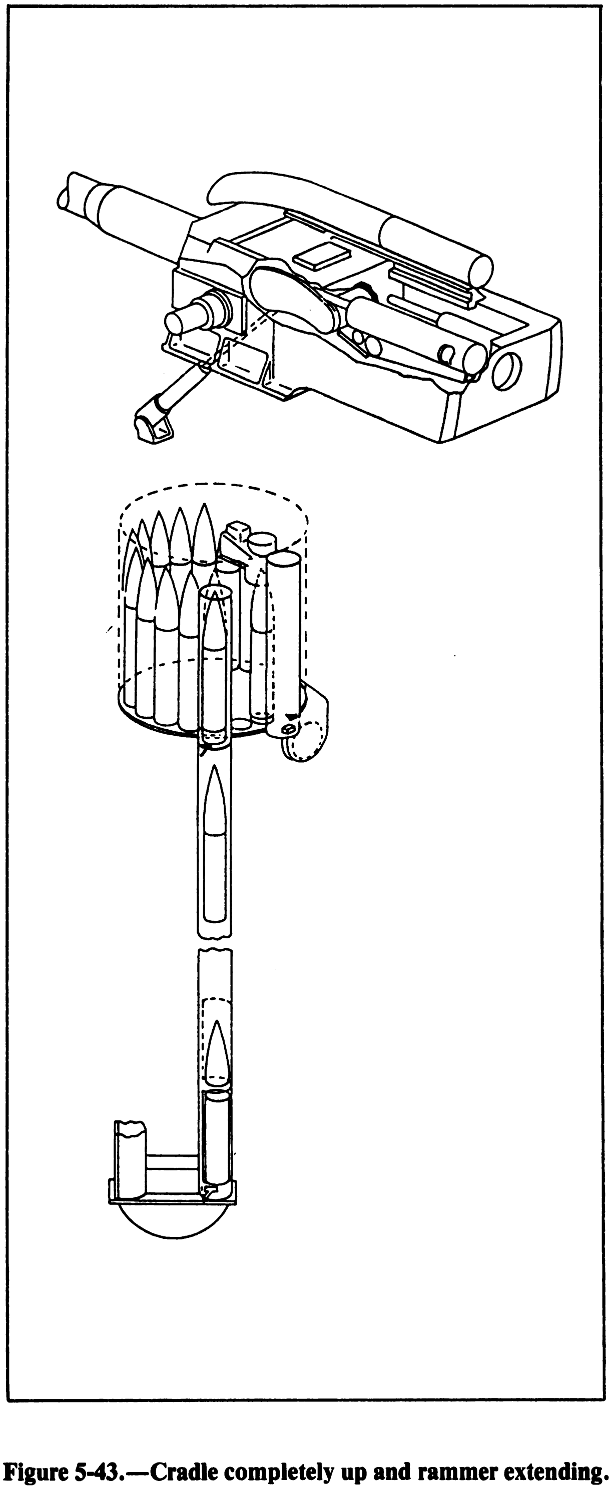

Figure 5-43.—Cradle completely up and rammer extending.

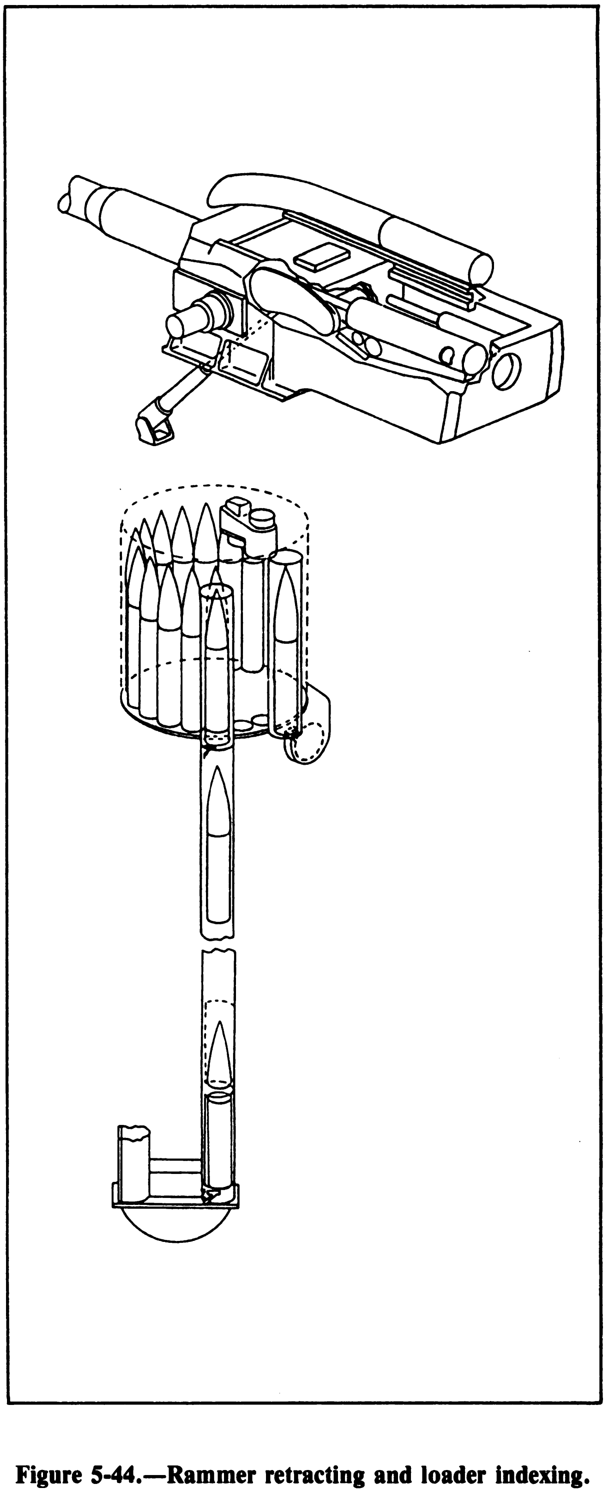

Figure 5-44.—Rammer retracting and loader indexing.

the **empty case tray** lowers to the fire position (fig. 5-45).

With all the loading system latched in the fire position, the gun fires and recoils (fig. 5-46). The breechblock lowers, the empty case is

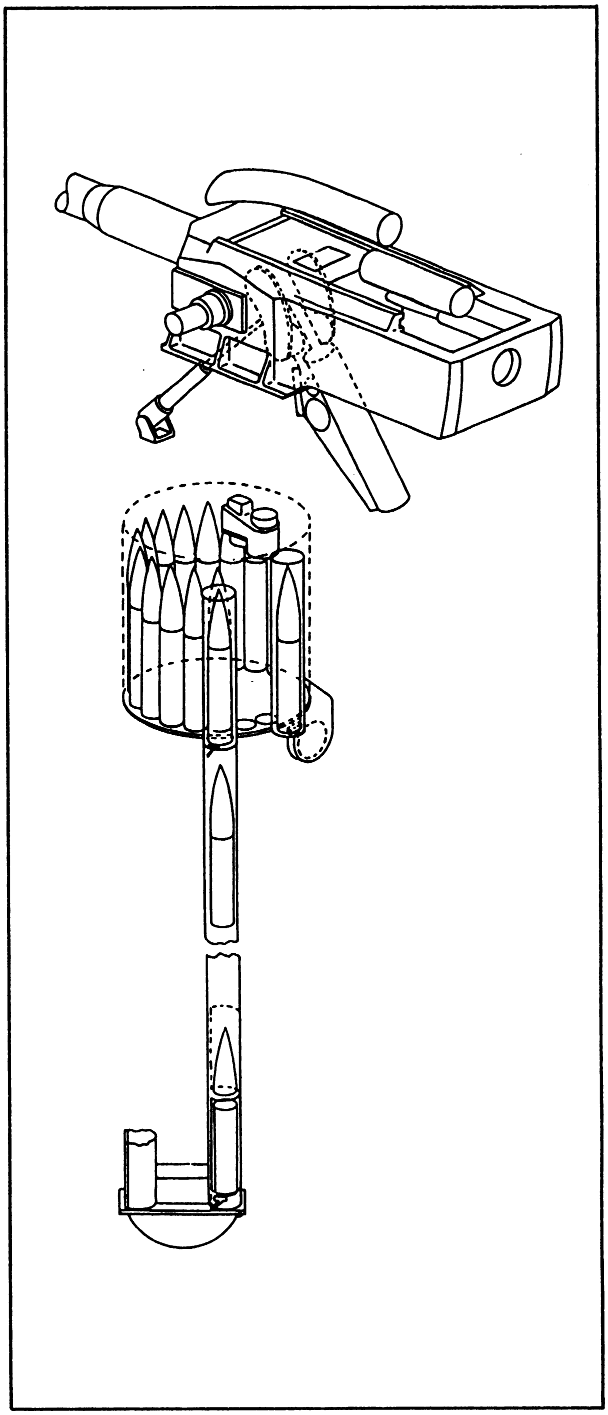

Figure 5-45.—Cradle lowers, breechblock closes, and empty case tray lowers to the fire position.

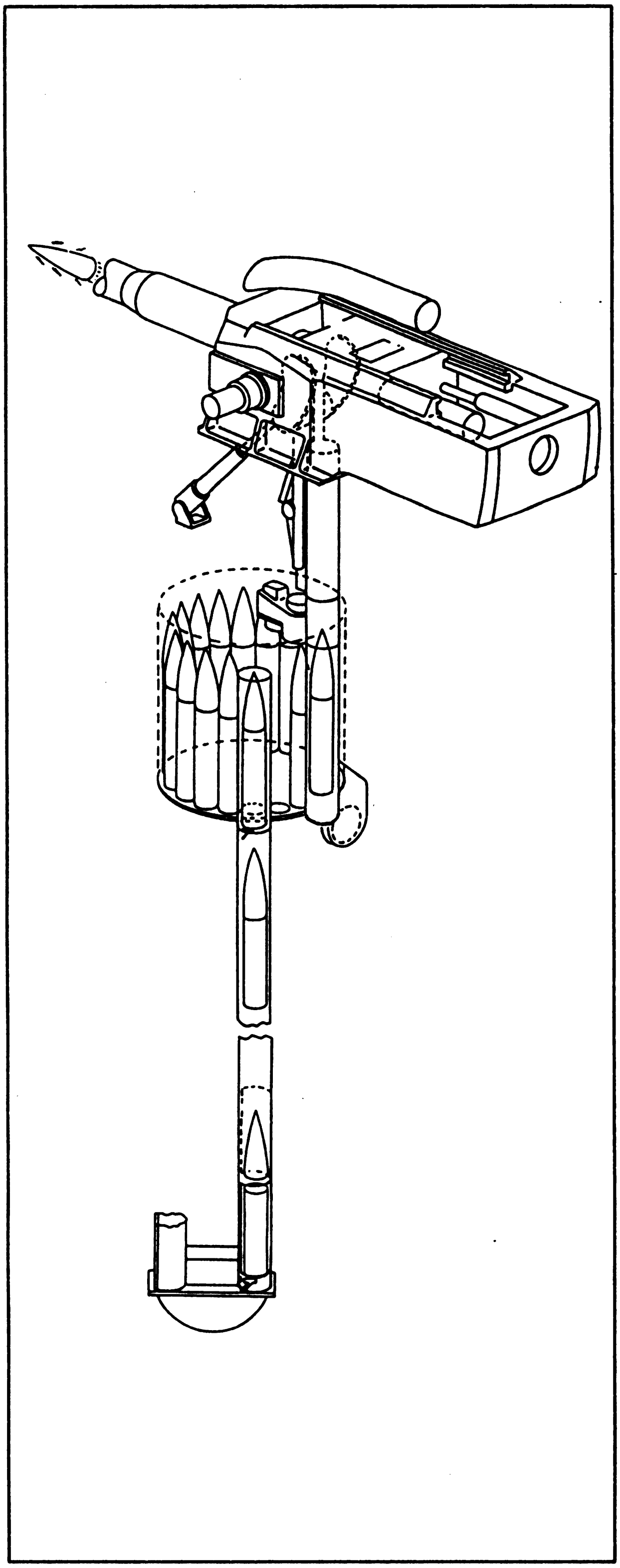

Figure 5-46.—The gun fires and recoils.

ejected into the empty case tray, and another round is raised into the cradle by the upper hoist (fig. 5-47).

As the cradle raises to ram the second round, the empty case tray raises to align with the case ejector (fig. 5-48). The empty case is ejected out on the deck at the same time the second round is rammed for firing.

This completes one firing cycle. As with the Mk 42 gun, the loading system continuously keeps each station full as rounds are fired.

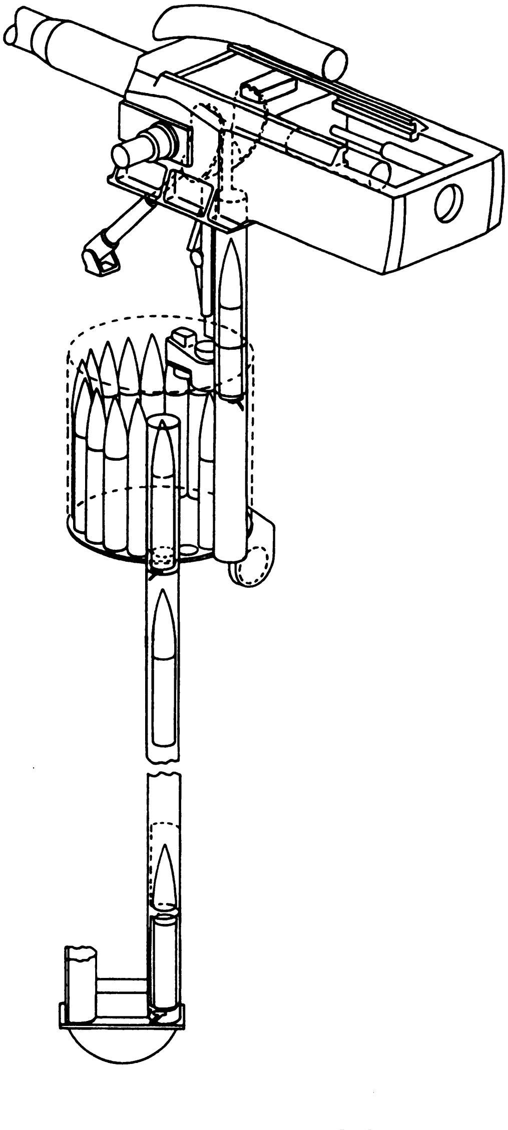

Figure 5-47.—The breech opens and the empty case is ejected.

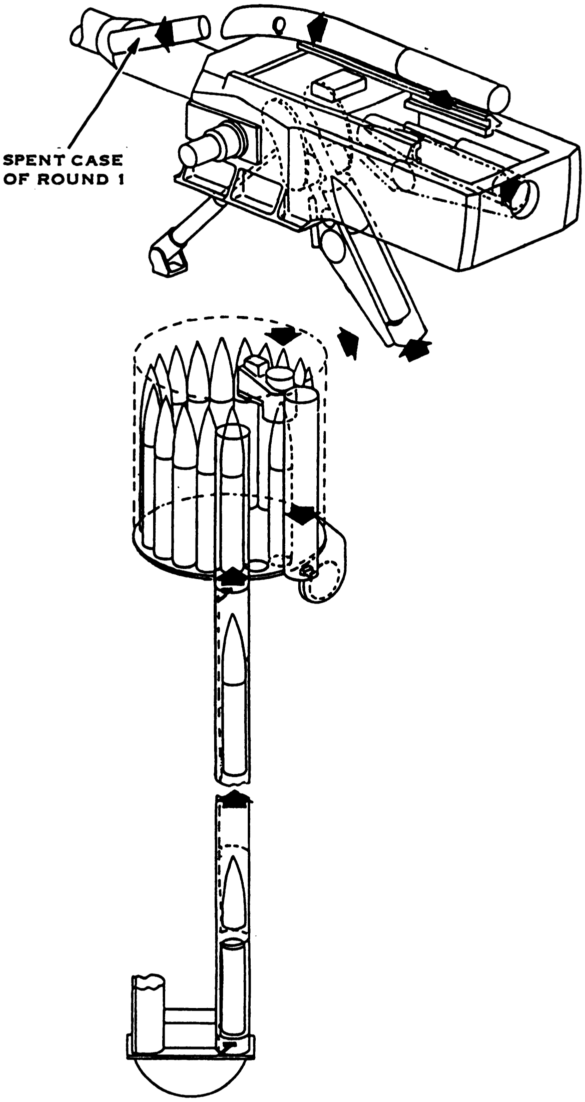

Figure 5-48.—The cradle and empty case tray raise to ram the second round and eject the empty case.

THE 76-MM MK 75 GUN

The Mk 75 gun (fig. 5-49) is a fully automated, remotely controlled gun mount that stows, aims, and fires 76-mm 62 caliber ammunition. The system is currently aboard FFG-7 and PHM class ships along with the Mk 92 GFCS. The design of the gun mount makes extensive use of lightweight corrosion-resistant alloys and modern engineering techniques. The result is a lightweight, compact, fast-firing, versatile weapon. It is primarily a defensive weapon, used to destroy antiship cruise missiles. However, it can also be effectively used against surface and shore targets. The gun has a

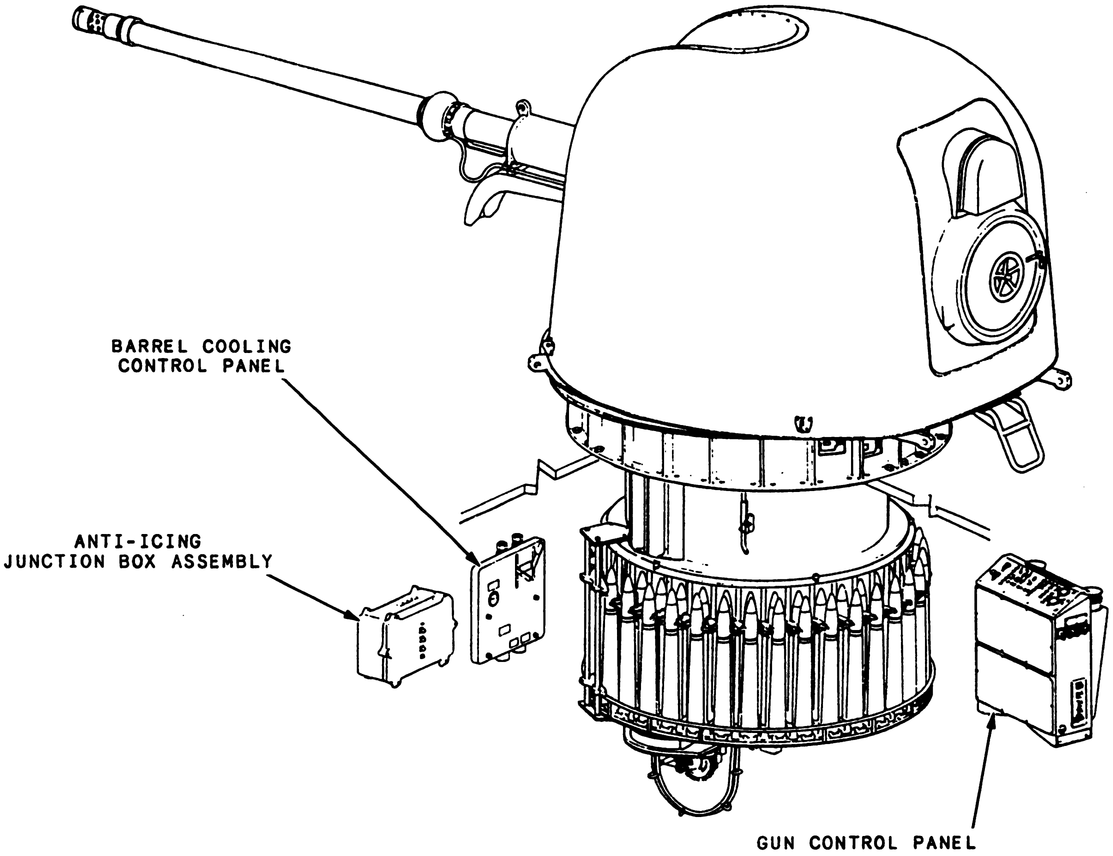
BARREL COOLING CONTROL PANEL
ANTI-ICING JUNCTION BOX ASSEMBLY
GUN CONTROL PANEL

Figure 5-49.—The Mk 75 gun system, general configuration.

variable rate of fire of up to 80 rounds per minute with a range of up to 16,459 meters and a maximum altitude of 11,519 meters. The most notable innovation featured on this system is the automatic barrel cooling system. This allows sustained operation at high rates of fire, without excessive barrel wear or the danger of a "cookoff" if a misfire occurs.

The Mk 75 gun fires a somewhat limited variety of ammunition types. The types of ammunition currently available include: point detonating (PD), infrared (IR), radio frequency (RF), and blind-loaded and plugged (BL&P).

Crew Positions and Responsibilities

The gun mount crew consists of the mount captain, two loaders, and the safety observer.

The mount captain is stationed in the ammunition handling room at the gun control panel (GCP). It is his responsibility to set the gun up for the desired mode of operation, then monitor it, in case of a malfunction. In case of a malfunction or misfire, the mount captain supervises and directs the corrective action.

The two loaders are stationed in the ammunition handling room during loading and unloading operations. Their primary duties are to load and unload the gun, clear misfires, and assist in corrective maintenance.

The safety observer is stationed topside, near the gun. His responsibility is to monitor the gun and the area around the gun for any unsafe condition. The safety observer is in direct contact with the mount captain.

We will now describe the loading system, as we walk through a loading sequence.

Loading Sequence

The ammunition handling system (fig. 5-50) for the Mk 75 gun mount moves ammunition from the revolving magazine to the last station loader drum, where the ammunition is subsequently deposited into the transfer tray, rammed, and fired. The handling system holds a maximum of 80 rounds. When a round is fired, each of the other rounds advances one position.

The handling system consists of the revolving magazine, the screw feeder and hoist system, the right and left rocking arm assemblies, and the hydraulic power unit. The entire loading system moves with the gun in train. The loader drum, which is a slide-mounted component, moves with the gun in elevation.

The hydraulic power unit, mounted to the carriage, provides hydraulic pressure to operate the loading system.

Ammunition is manually loaded into the revolving magazine. The revolving magazine consists of two concentric circles of stowage cells, each holding 35 rounds of ammunition. The

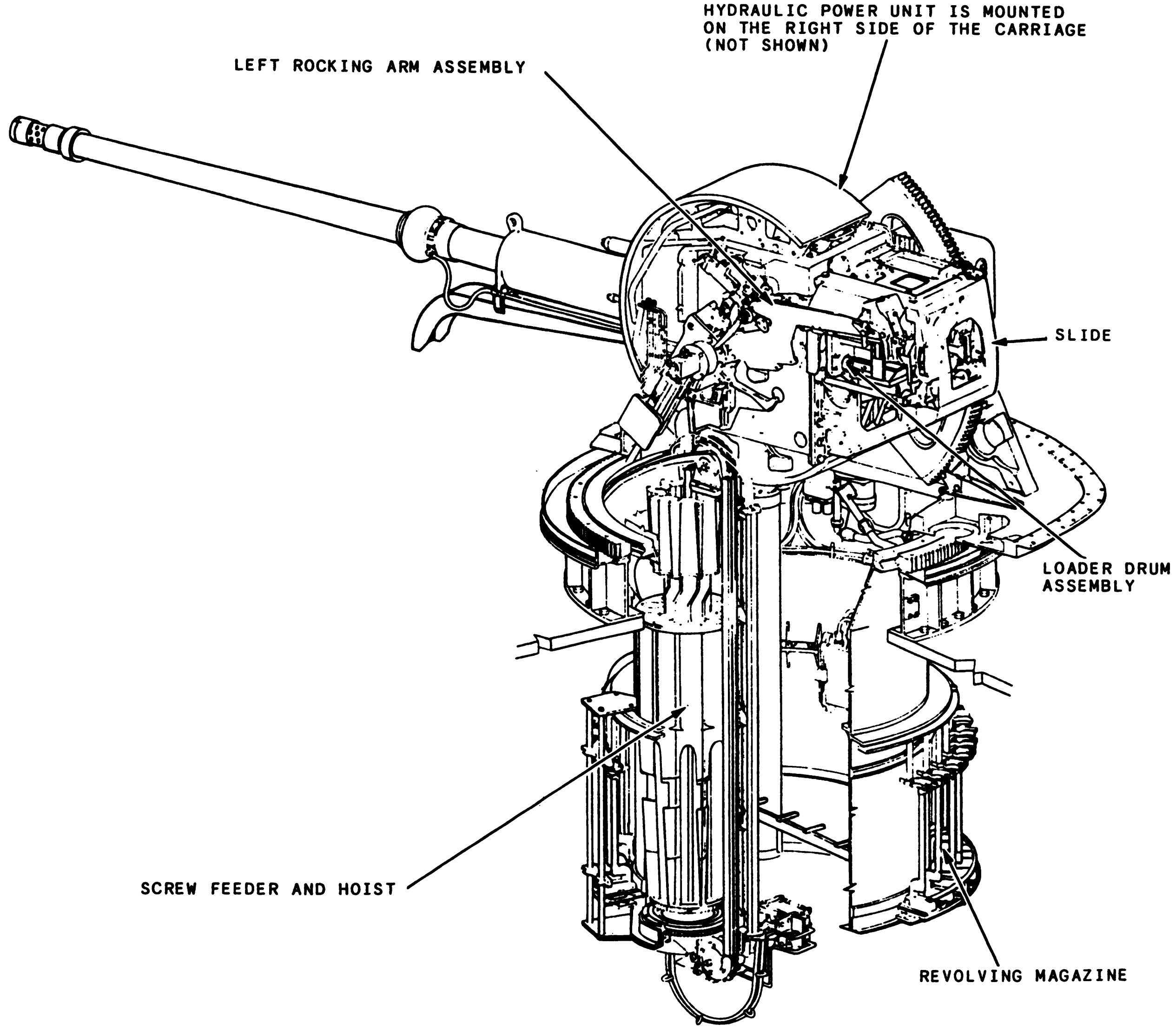
HYDRAULIC POWER UNIT IS MOUNTED ON THE RIGHT SIDE OF THE CARRIAGE (NOT SHOWN)
LEFT ROCKING ARM ASSEMBLY
SLIDE
LOADER DRUM ASSEMBLY
SCREW FEEDER AND HOIST
REVOLVING MAGAZINE

Figure 5-50.—The Mk 75 gun loading system; major components.

revolving magazine turns when the hydraulic motor rotates the screw feeder.

During rotation of the revolving magazine and screw feeder (fig. 5-51), a round moves from the inner circle of stowage cells to the screw feeder. When a round leaves the inner circle of cells, a round from the outer circle replaces it, leaving an empty cell in the outer circle.

When a round reaches the screw feeder, it is lifted in a spiraling manner by the hoist lift pawl assemblies of the hoist as the screw feeder rotates

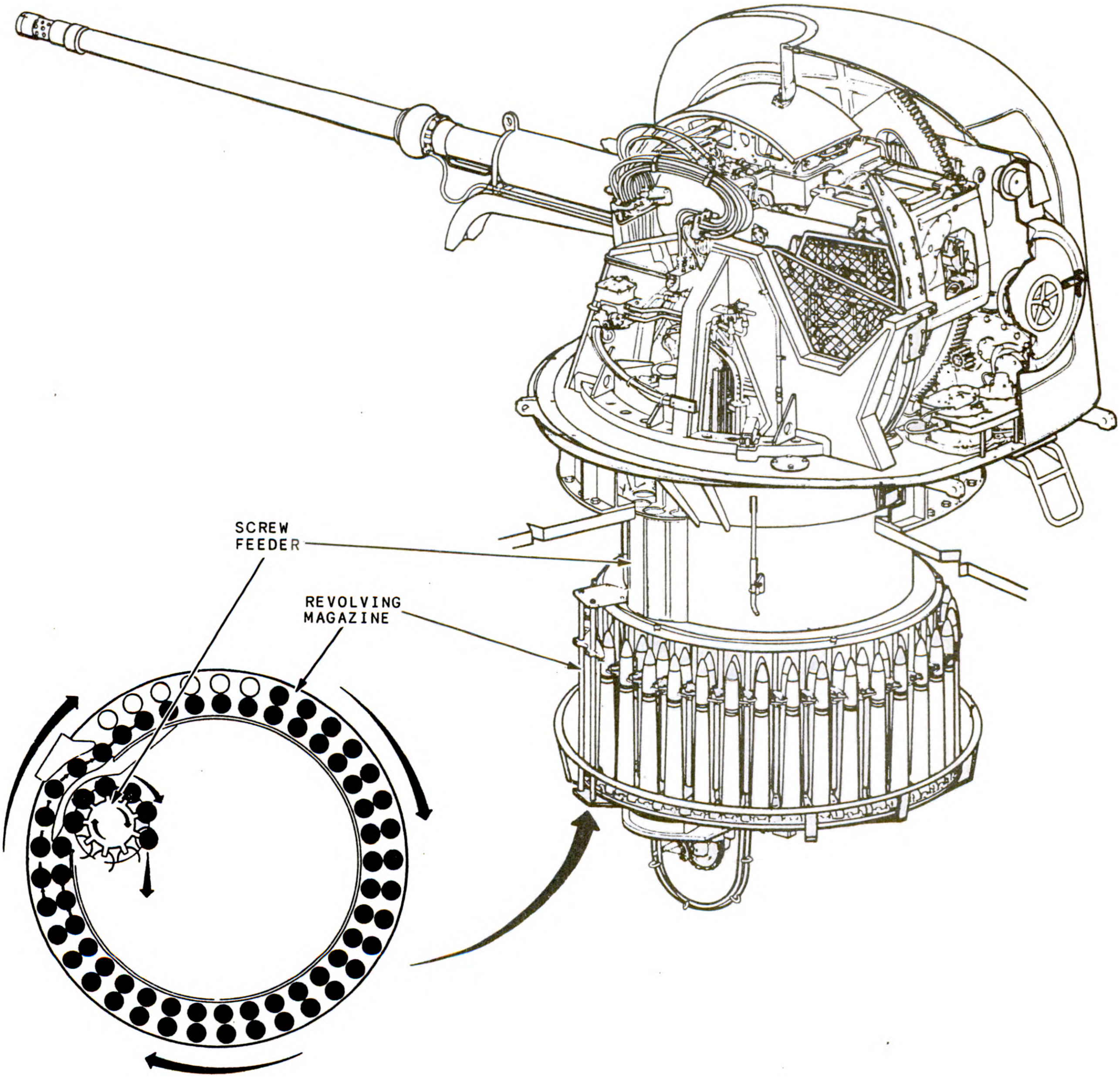

Figure 5-51.—Movement of rounds in the revolving magazine and screw feeder.

(fig. 5-52). The screw feeder, with a capacity of six rounds, delivers a round to the rocking arms. The rocking arms alternately raise rounds to the loader drum (fig. 5-53). While one rocking arm is lifting a round to the loader drum, the other arm is returning empty to pick up the next round from the screw feeder.

The loader drum has a capacity of four rounds. As the loader drum receives a round from the rocking arm, it rotates to deposit the round in the last station of the loader drum, and then

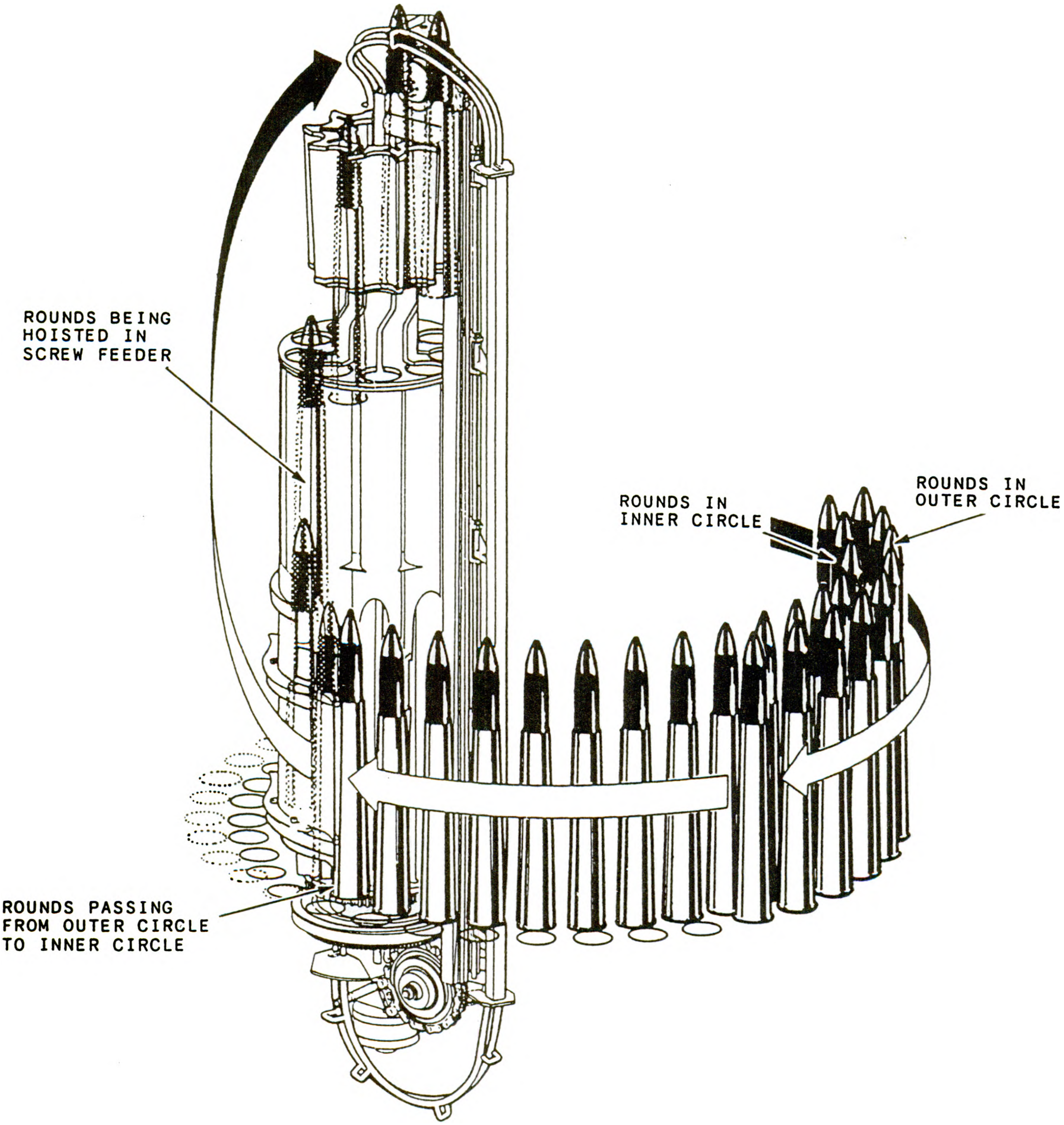
ROUNDS BEING HOISTED IN SCREW FEEDER
ROUNDS IN INNER CIRCLE
ROUNDS IN OUTER CIRCLE
ROUNDS PASSING FROM OUTER CIRCLE TO INNER CIRCLE

Figure 5-52.—Ammunition flow from the revolving magazine through the screw feeder.

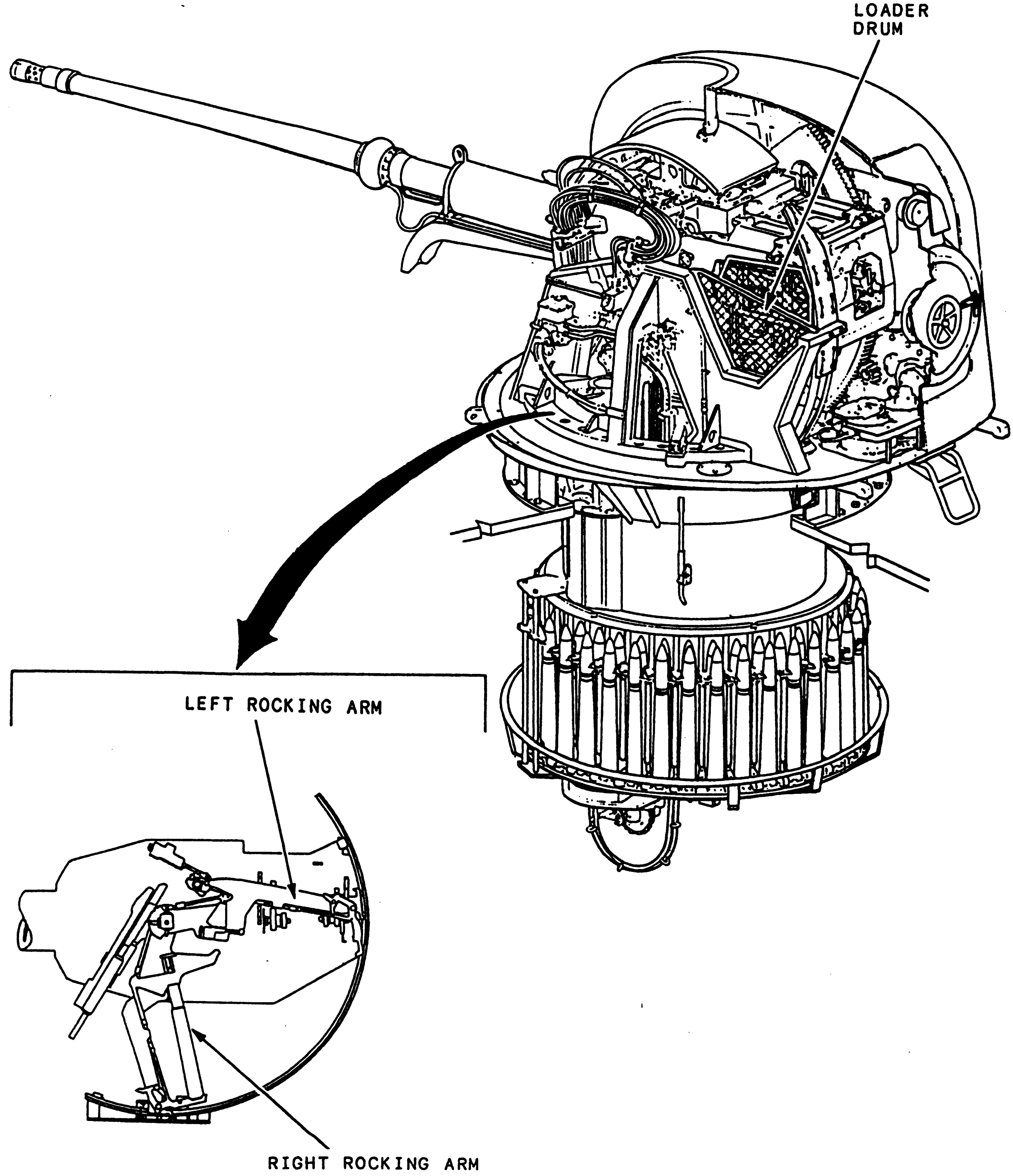

Figure 5-53.—Movement of rounds from screw feeder to loader drum.

into the transfer tray for subsequent ramming and firing (fig. 5-54). The Mk 75 gun system uses a percussion firing system.

During recoil, the breechblock is lowered and the empty case is extracted into the empty case tray from which it is ejected out of the system. This completes the loading cycle for one round.

THE 16"/50 GUN TURRET

The 16" gun is currently the largest gun in existence. Originally introduced in the 1940s, the BB-61 Iowa class battleships and their 16"/50 guns have seen action in WW II, Korea, and Vietnam. They continue to be an impressive tool of U.S. foreign policy; most recently in areas such as Lebanon, the Persian Gulf, and Central America.

These big guns have been in the news recently for another reason which bears comment. The 1989 explosion in turret 2 aboard the USS Iowa killing 47 sailors, graphically illustrates the dangerous nature of work in the ordnance world. There is no room for error when dealing with explosives.

Together with the Mk 38 GFCS, the three 16"/50 turrets aboard the four Iowa class battleships make up the ship's main battery. Each

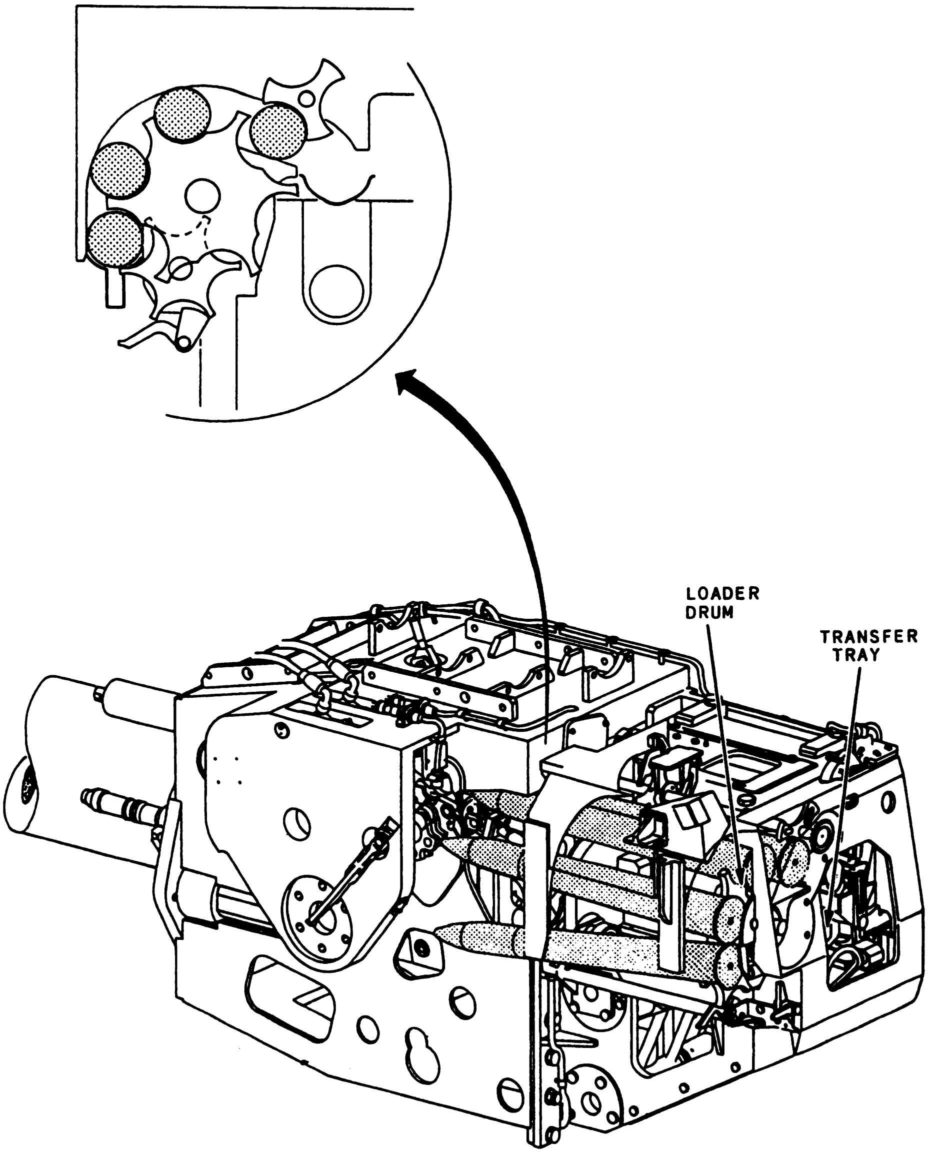

Figure 5-54.—Movement of rounds in loader drum.

turret contains three guns chambered to fire ammunition using bagged powder charges. The guns have an approximate rate of fire of two rounds per minute. The fire of all nine guns can be concentrated on a surface or shore target on either beam at a maximum range of 41,000 yards.

Located on the ship's centerline, turrets 1, 2, and 3 are virtually the same, differing only in minor details, which adapt each turret to its location. Each turret comprises a gunhouse and rotating structure, a fixed structure, and magazines (fig. 5-55).

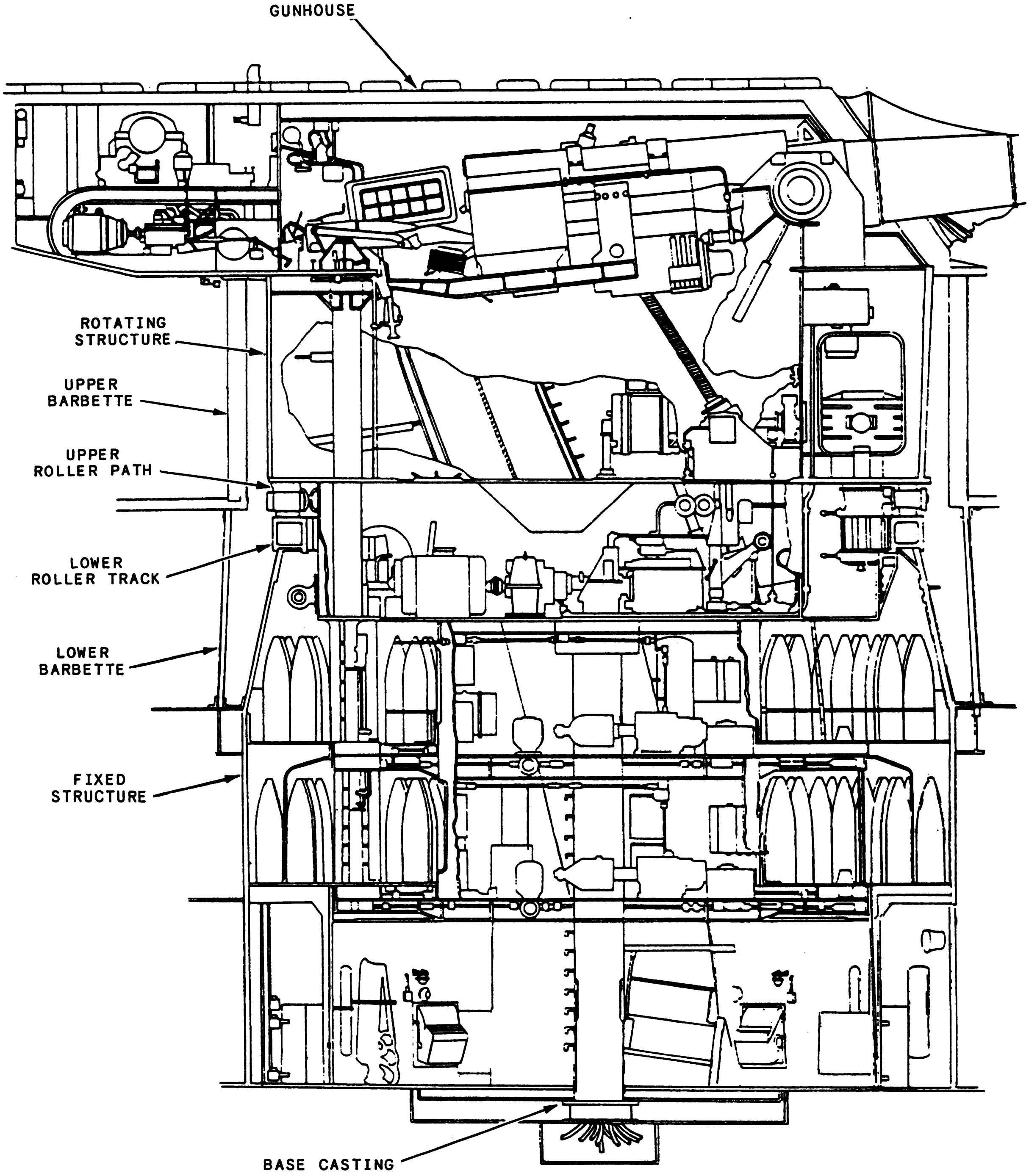

Figure 5-55.—16"/50 gun turret, general arrangement.

The gunhouse is mounted above and attached to the rotating structure and is divided into three gun rooms (fig. 5-56). The rotating structure is supported by the roller path and consists of 6 deck levels (fig. 5-57). Turret 2 has a seventh deck level, which is part of the fixed structure and provides additional projectile stowage.

The fixed structure consists of all stationary structures used to support and protect the rotating and installed equipment.

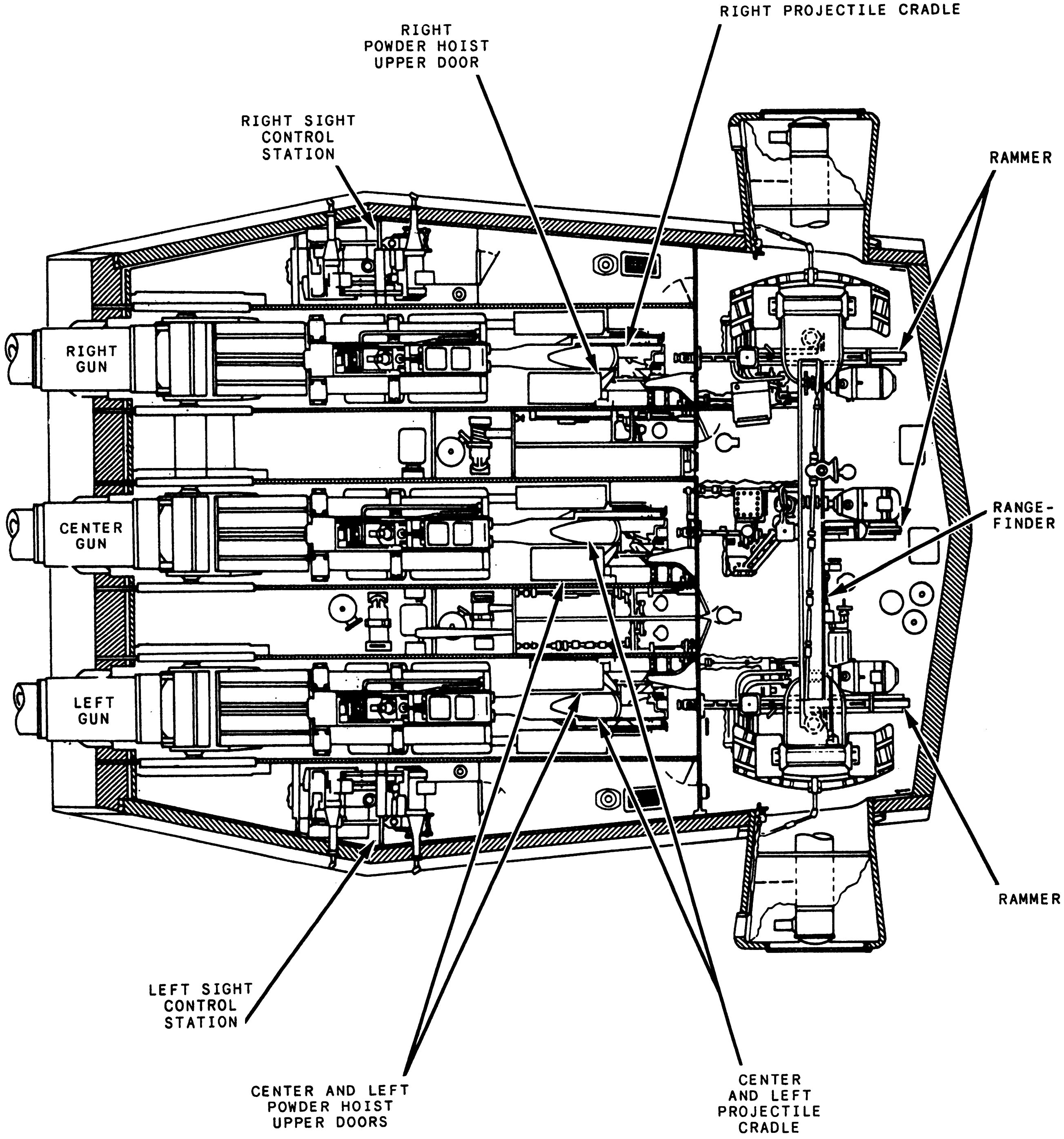
RIGHT PROJECTILE CRADLE
RIGHT POWDER HOIST UPPER DOOR
RIGHT SIGHT CONTROL STATION
RAMMER
RIGHT GUN
CENTER GUN
LEFT GUN
RANGE-FINDER
RAMMER
LEFT SIGHT CONTROL STATION
CENTER AND LEFT POWDER HOIST UPPER DOORS
CENTER AND LEFT PROJECTILE CRADLE

Figure 5-56.—Gunhouse general arrangement.

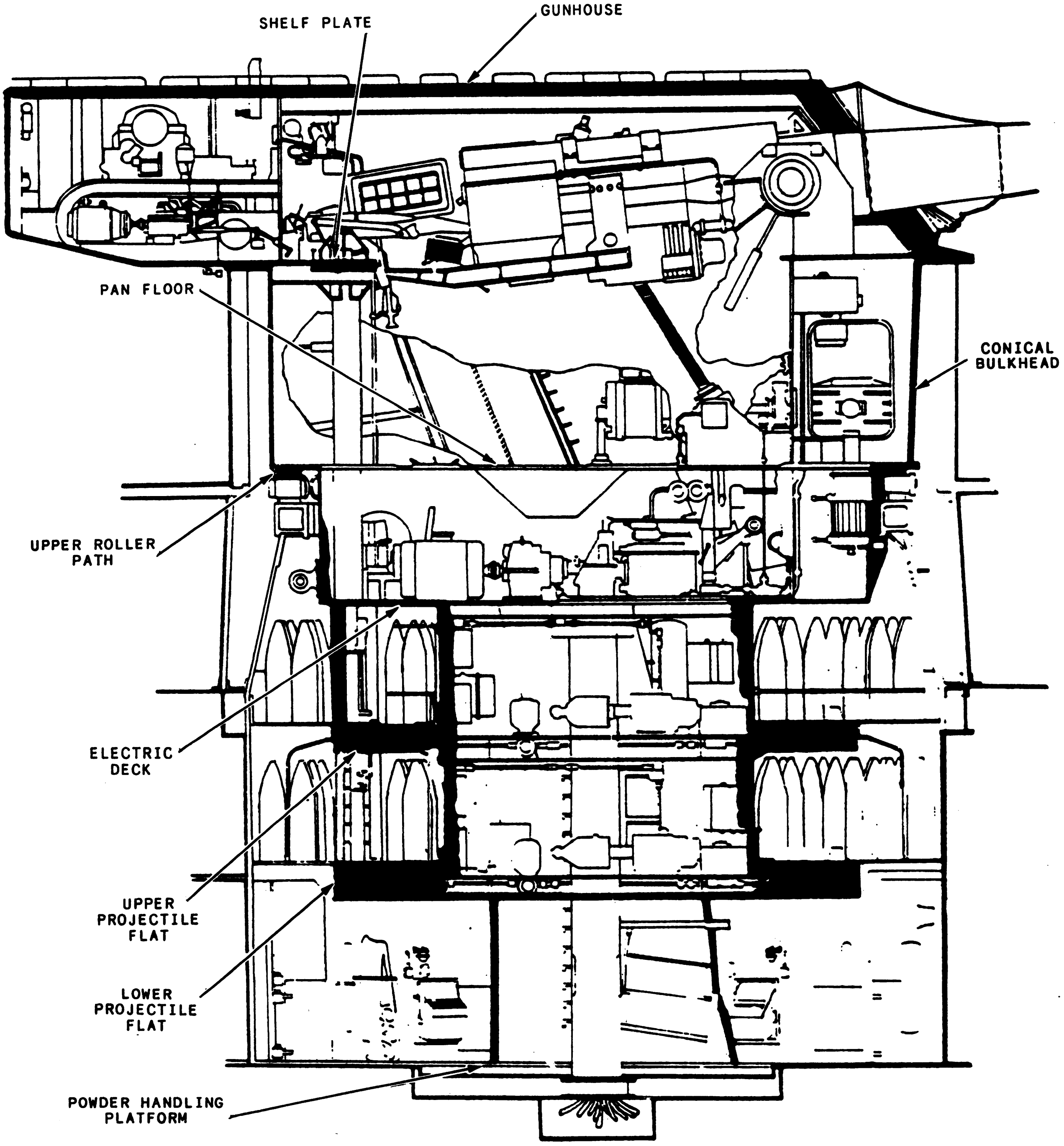

Figure 5-57.—Turret rotating structure.

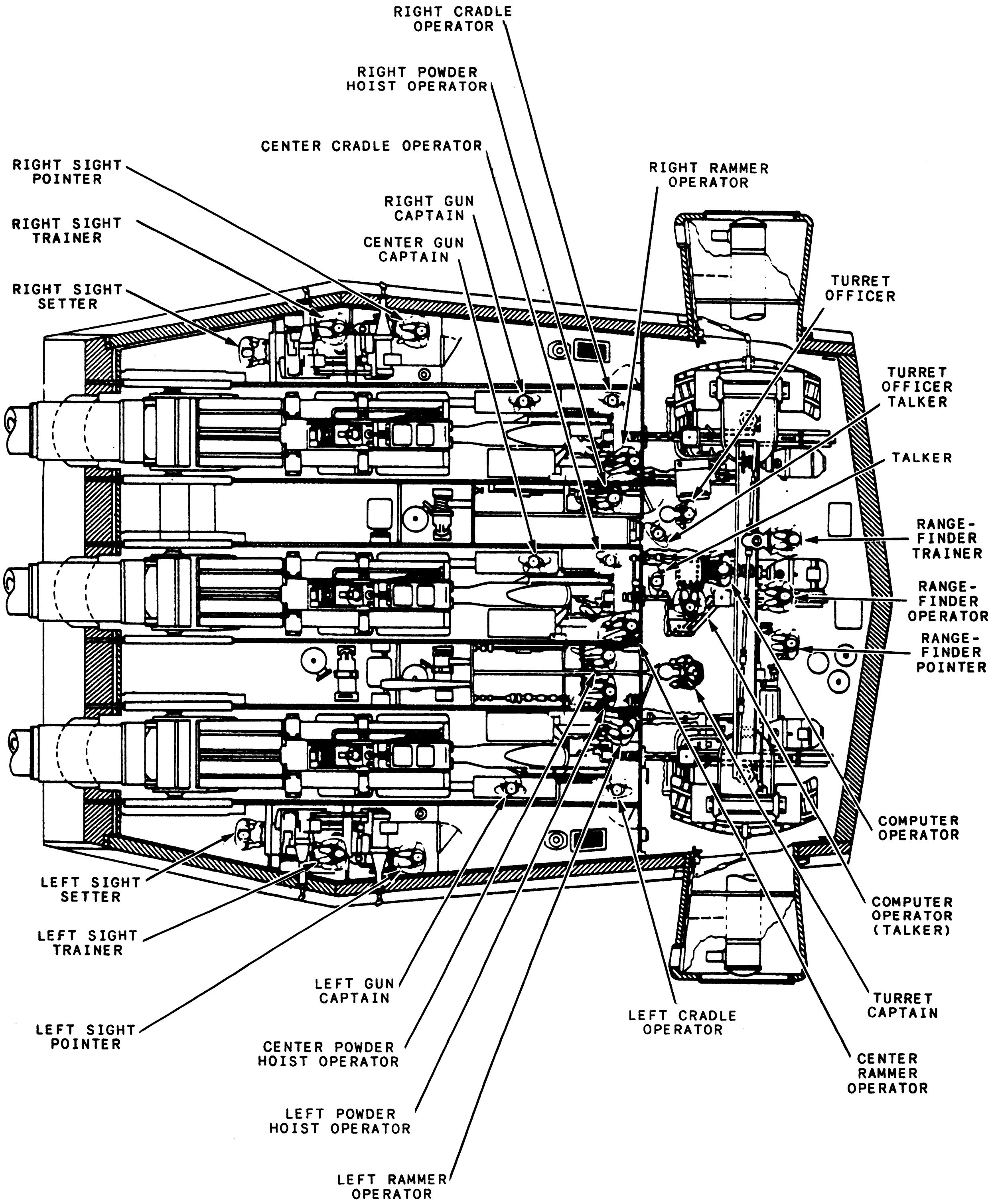

Figure 5-58.—Turret personnel arrangement, gunhouse stations.

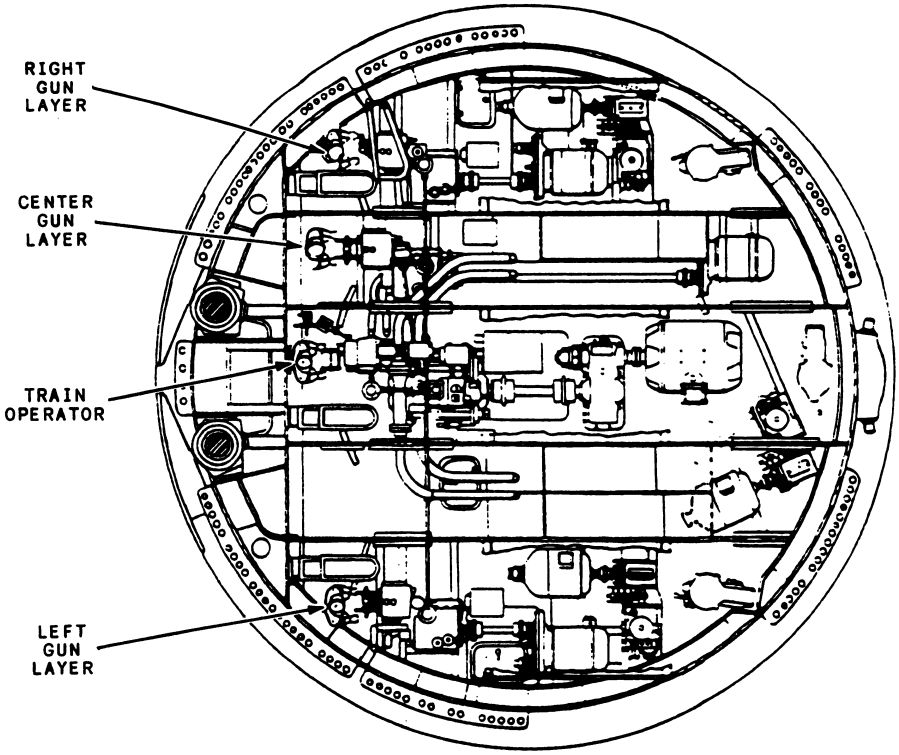

Figure 5-59.—Turret personnel arrangement, electric deck stations.

Crew Positions and Responsibilities

Figures 5-58, 5-59, 5-60, and 5-61 illustrate the many positions manned in a 16"/50 turret during operation. Because of the large number of personnel involved, we will describe the crew stations as we go through the loading sequence—not all positions will be described.

Loading Sequence

Once start-up procedures have been finished, and the turret officer determines that loading can begin, he orders the guns loaded. He first designates which projectile flat will serve the hoists, and the type of projectile to be loaded.

On the chosen flat, two shellman/parbucklers work as a team to parbuckle projectiles from the inner ring into the hoist aperture. The shellman put the hook on the end of the parbuckler snubbing line into a convenient hole or eye, provided for that purpose. The parbuckler operates the snubbing line, looping the free end of the line twice around a gypsy head and pulling it tight enough to move the projectile into the hoist aperture. The projectile ring operator rotates the projectile ring after every three rounds so that the shellmen can reach the projectiles in stowage.

Three powdermen work as a team to load each powder hoist. Two powdermen operate the handling room scuttles, carry the powder bags, and load the powder cars. The third powderman operates a magazine scuttle to pass powder bags from the magazine to the handling room. Each powderman makes three trips to load six powder bags into the loading trays.

The projectile hoist has several flights to fill, the last of which places a round in the loading cradle. The powder hoist, however, is filled and raised to the gun house, then returned directly for another load.

The gun captain opens the breech and visually inspects for a clear bore. When a clear bore is announced, the primerman inserts a live primer into the firing lock.

With the gun at the 5-degree load position, the cradle is lowered by the cradle operator. The rammer operator then moves the rammer hand lever—first, to ram the projectile, and again to withdraw the rammer. The upper powder door is opened upon completion of the rammer withdraw actions. The first three powder bags are

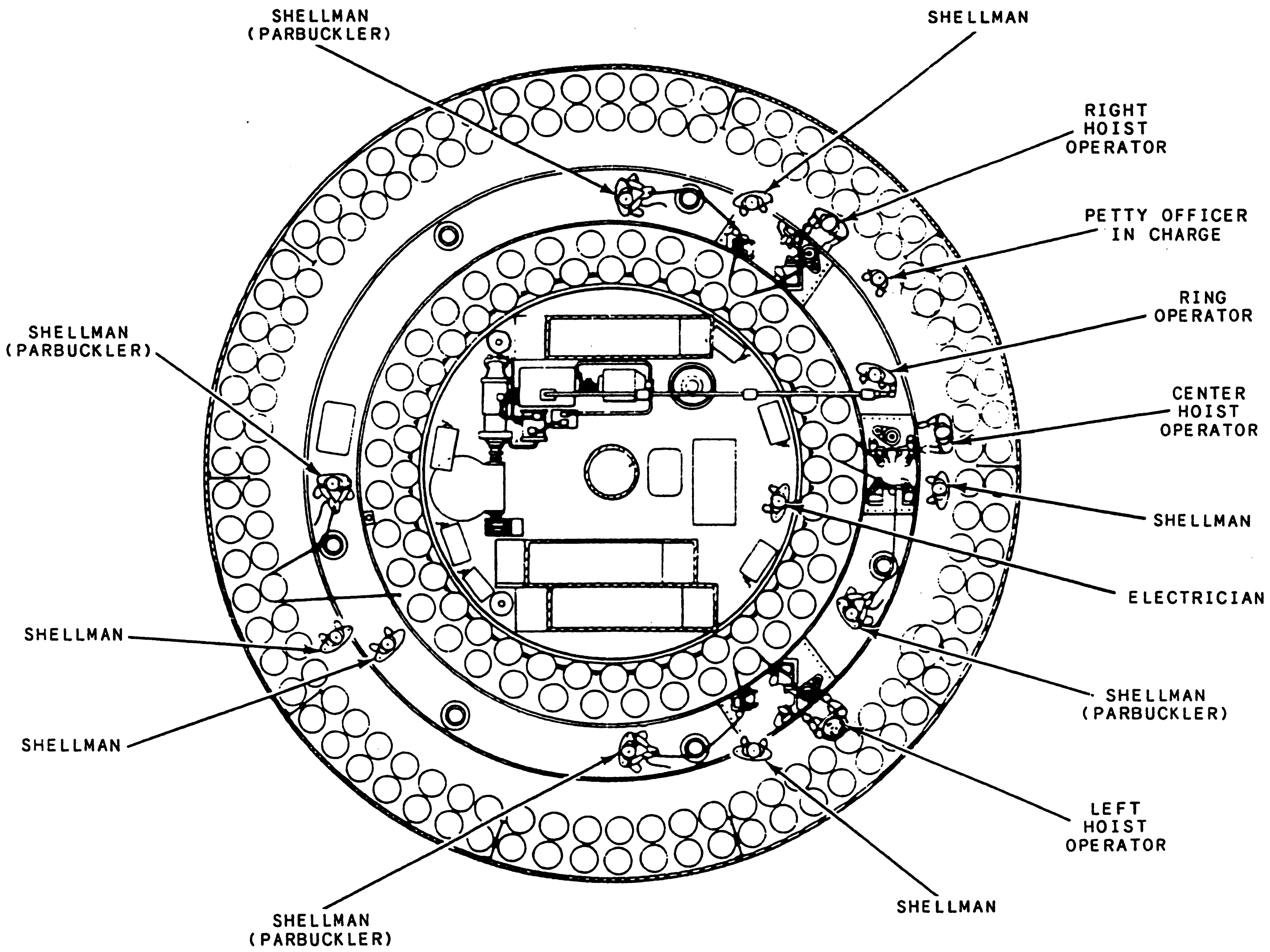

Figure 5-60.—Turret personnel arrangement, projectile flat stations.

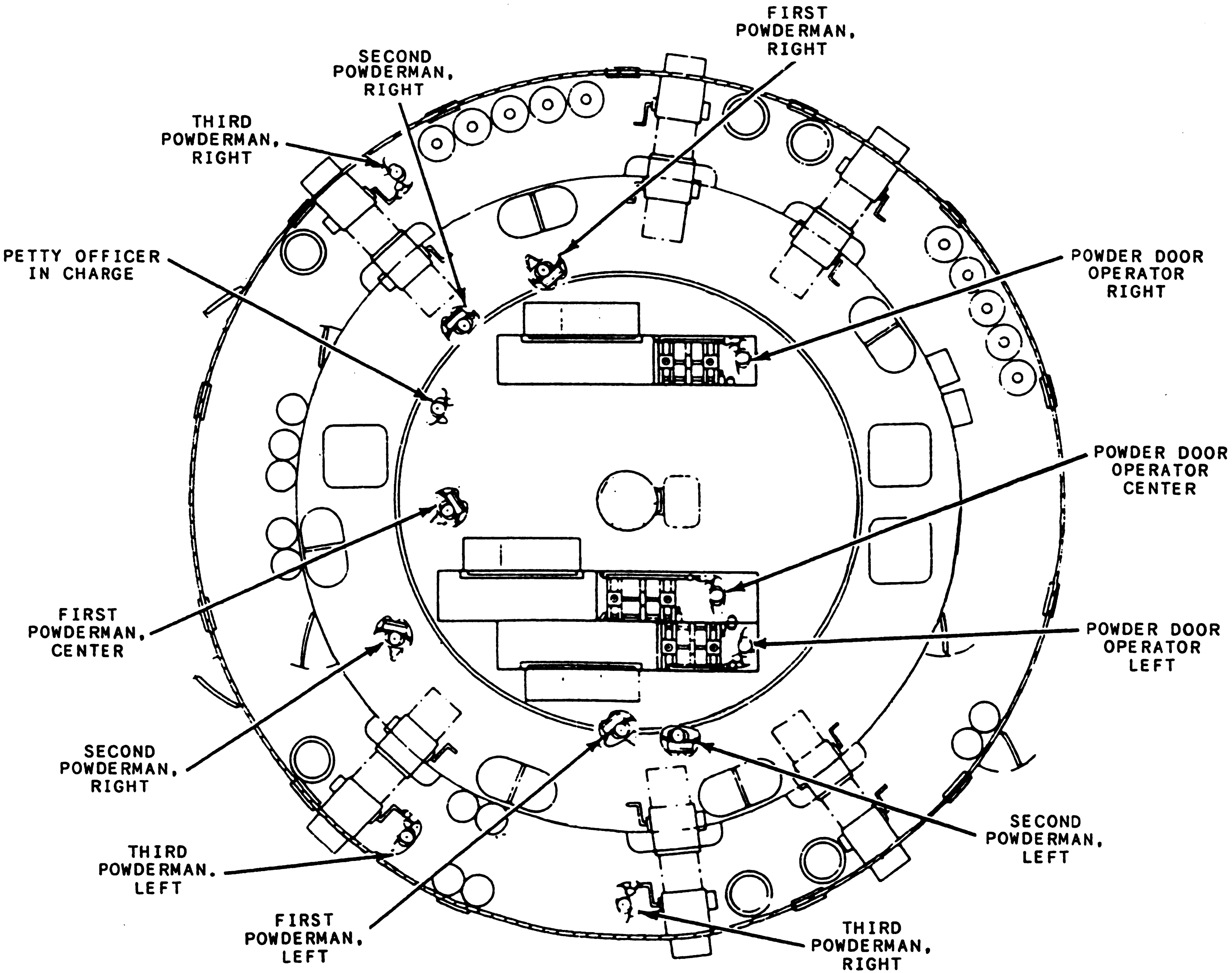

Figure 5-61.—Turret personnel arrangement, powder handling room stations.

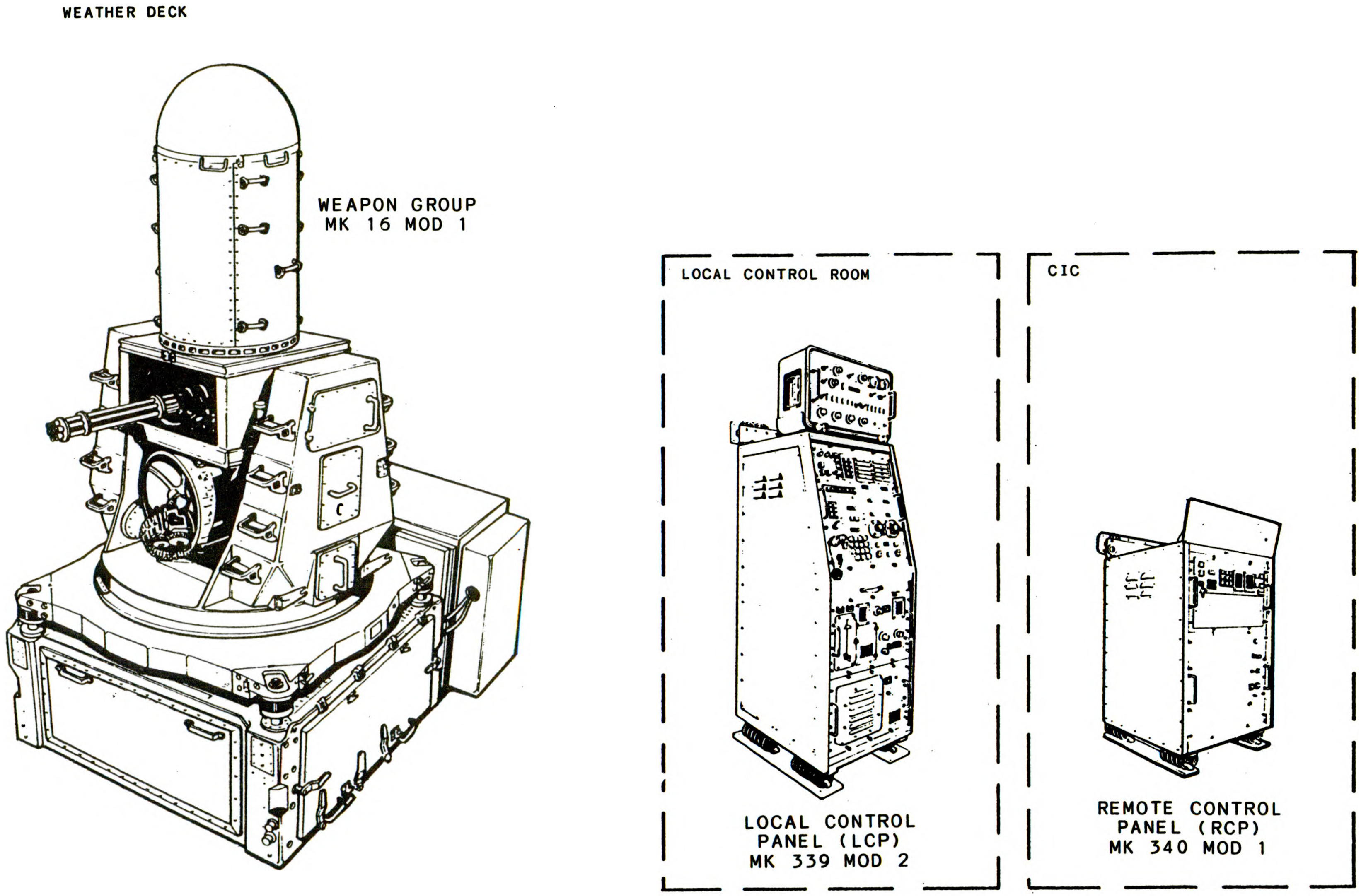
WEATHER DECK
WEAPON GROUP MK 16 MOD 1
LOCAL CONTROL ROOM
LOCAL CONTROL PANEL (LCP) MK 339 MOD 2
CIC
REMOTE CONTROL PANEL (RCP) MK 340 MOD 1

Figure 5-62.—CIWS basic system layout.

then rolled on to the spanning tray from the hoist. These are arranged to allow room for the final three bags to be placed on to the tray. Lead foil is then placed between the two forward bags and all six are rammed. The rammer operator withdraws the rammer, the upper powder door is closed, the cradle is raised out of the way, and the gun captain closes the breech. The gun can now be fired either locally or from a remote station.

Each turret can operate independently of an outside fire control system. This is possible because each turret has its own auxiliary fire control computer. Both turrets 2 and 3 have a range finder that supplies range information to the computer operator when in local or secondary control. Computer operators solve the fire control problem as a check when operating in primary or automatic control.

The gun layers and the train operator ensure the gun is at the ordered position. Each has a firing key that may be used to fire the gun when directed by the turret officer.

This concludes our discussion on the 16"/50 gun turret. We will now move on to our last system topic, the Close-In Weapon System.

THE CLOSE-IN WEAPON SYSTEM

The Close-in Weapon System (CIWS) (fig. 5-62) provides final defense against antiship cruise missiles (ASCM). Without assistance from other ship systems, CIWS will automatically search for, detect, track, fire on, and destroy targets that it determines are a threat to the ship.

The system is operated from either of two control panels— the Local Control Panel (LCP) or the Remote Control Panel (RCP). The system is not manned except at these two positions. The system mounts a 20-mm M61A1 Gatling gun, which has a 3000 round per minute rate of fire, with a system capacity of 980 rounds. The gun fires a specialized type of depleted uranium projectile, fired inside a discarding sabot (fig. 5-63).

We will describe this unique system and its major components by walking through a complete cycle from search to target destruction.

Once the system is energized and placed in the primary autonomous mode, the system functions as follows. The search function is performed with the mount deactivated. The mount will normally be at zero degrees elevation and in the center of the firing zone in train at this time. The search radar looks for targets with an elevation between zero and five degrees true. When a target is detected, its range, bearing, range rate, and height are determined and assessed by the weapon control group (WCG) to determine if the target is a threat. If determined to be a threat, it is designated by the WCG/computer for engagement.

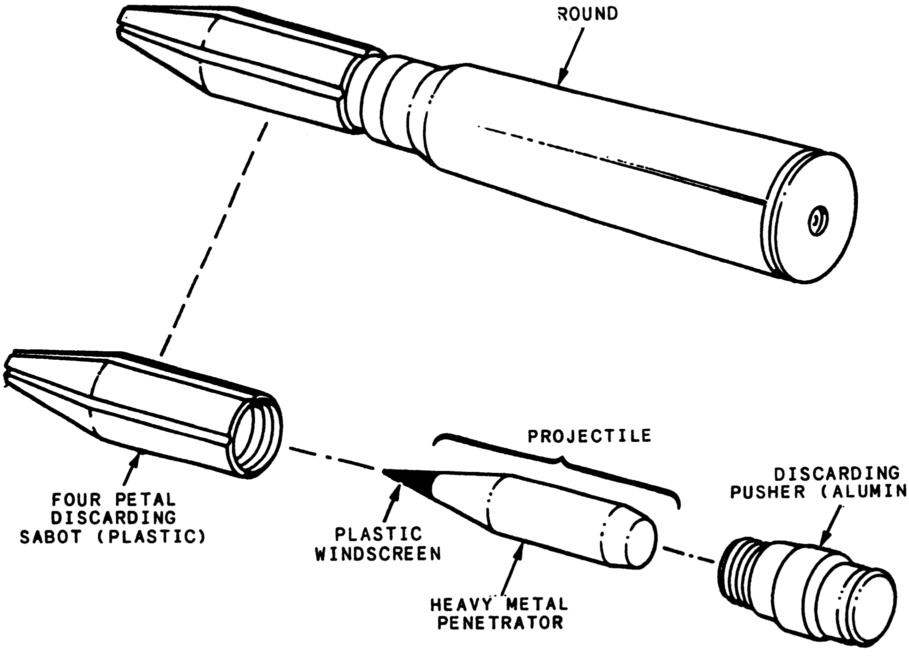
ROUND
PROJECTILE
DISCARDING PUSHER (ALUMINUM)
FOUR PETAL DISCARDING SABOT (PLASTIC)
PLASTIC WINDSCREEN
HEAVY METAL PENETRATOR

Figure 5-63.—Specialized round.

When a target is declared a threat, the system stops the search function and initiates the acquisition function. In the acquisition function, the WCG computer orders the gun to slew to the targets bearing and elevation, and orders the track radar to begin a localized area search pattern for the target.

When the track radar acquires the target, the WCG computer controls the antenna and mount servos to maintain the track. The radar provides range and range rate data to the WCG, which uses the data to generate gun aim orders. When the target reaches the computed engagement range, the computer orders the gun to commence firing. As the gun fires, the computer with radar data on both the target and the rounds fired generates correction orders for the gun. This process continues until the target is destroyed. When the computer determines that the target has been destroyed, it returns the CIWS to the search mode.

This section on the CIWS is necessarily short because of the classified nature of most of the information pertaining to the system.

MAINTENANCE AND PRE-FIRE REQUIREMENTS

Maintenance on the systems we have just described ranges from the simplest (i.e., lubrication) to very technical (i.e., balancing an amplifier). Gone are the days when a Gunner's Mate was concerned only with simple maintenance. Today's systems require a technician with a wide variety of skills. He must be able to maintain, troubleshoot, and repair mechanical, electric, electronic, and hydraulic devices.

Some of the maintenance actions that are peculiar to guns involve barrel inspections. These include the annual inspection for gun barrel wear called **Star Gauge**. This inspection is normally accomplished by a support activity such as a tender or Ship's Intermediate Maintenance Activity (SIMA). The inspection derives its name from the shape of the device used to determine the amount of wear of the barrel's rifling (fig. 5-64).

The other inspection, accomplished by the ship's force, is accomplished to determine barrel wear at the forcing cone. This is the tapered area between the smooth gun chamber and the smaller rifled section of the barrel. This is where the rifling begins. As the gun is repeatedly fired, this area is subjected to severe heat and force. The Projectile Seating and Distance Gauge (PSDG) measures the wear at this point, reading in percentage of barrel wear. This inspection is required after every 50 rounds fired or, as a minimum, once a quarter.

The data from these two inspections is critical to the ballistic calculations used to solve the fire control problem. They both influence the calculation of the gun's **initial velocity**, which we will discuss in a later chapter.

These inspection results, and any other data impacting gun alignment or ballistics, are recorded in the **battery smooth log**, normally maintained by the Fire Controlmen. This is a critical log that you as a division officer should be concerned with.

The pre-fire requirements for all major caliber guns center on the inspection of the fluid levels and air pressures in the critical subsystems such

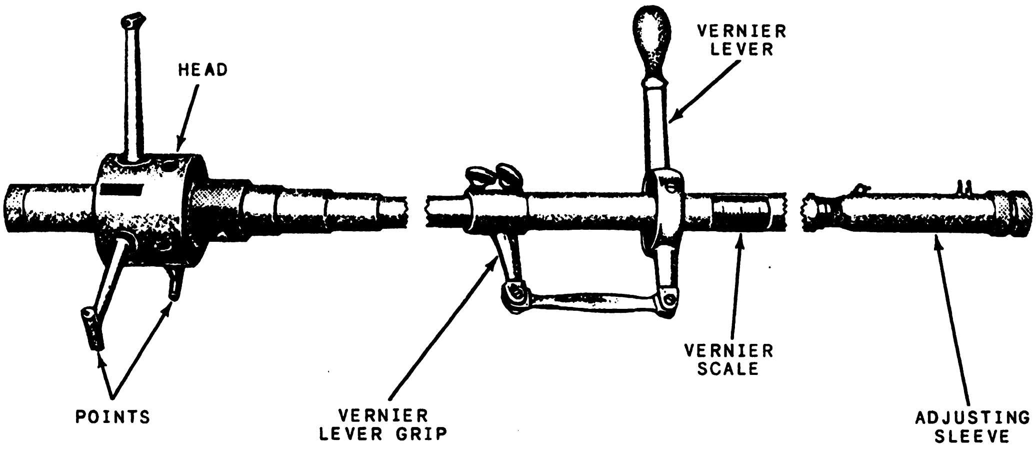

Figure 5-64.—The star gauge.

as recoil and counterrecoil. These inspections are required to be accomplished by a commissioned officer. Other inspections include system operability, firing circuit, and transmission checks between controlling stations. All pre-fire requirements are listed step-by-step on a **maintenance requirement card (MRC)**. It is obviously imperative that these procedures be followed to the letter.

SUMMARY

In this chapter we began by describing gun positioning and firing equipment. We described the gun systems currently in the fleet, focusing on their loading systems. In the final section of this chapter, we briefly described gun pre-fire requirements. In the next chapter, we will describe the fundamentals of the different guided missiles currently in service.

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CHAPTER 6

GUIDED MISSILES

In this chapter we will explain the fundamentals of naval missiles, including their major components, and the current types now in the fleet. Since much of the information pertaining to naval missiles is classified, our explanation of their function will necessarily be very general in nature.

Before we begin, let's recall the definition of a guided missile. "A guided missile is a self-propelled projectile whose path can be changed in flight through its own internal mechanisms." Naval missiles are fired from nearly all platforms and are used to destroy a variety of targets. The Navy uses surface-to-air, surface-to-surface, air-to-air, air-to-surface, and subsurface-to-surface missiles. In this chapter we will discuss only surface-to-air and surface-to-surface missiles. Some of these missiles can be launched from both submarines and aircraft as well as surface vessels. These capabilities will be pointed out in this text. Air-to-air and air-to-surface missiles are covered in a later chapter.

GUIDED MISSILE FUNDAMENTALS

Every guided missile contains equipment to perform four basic functions: guidance, control, propulsion, and destruction. Each missile can be broken down into these four sections. We will first describe these functions, then the components that perform them. Figure 6-1 shows a Standard

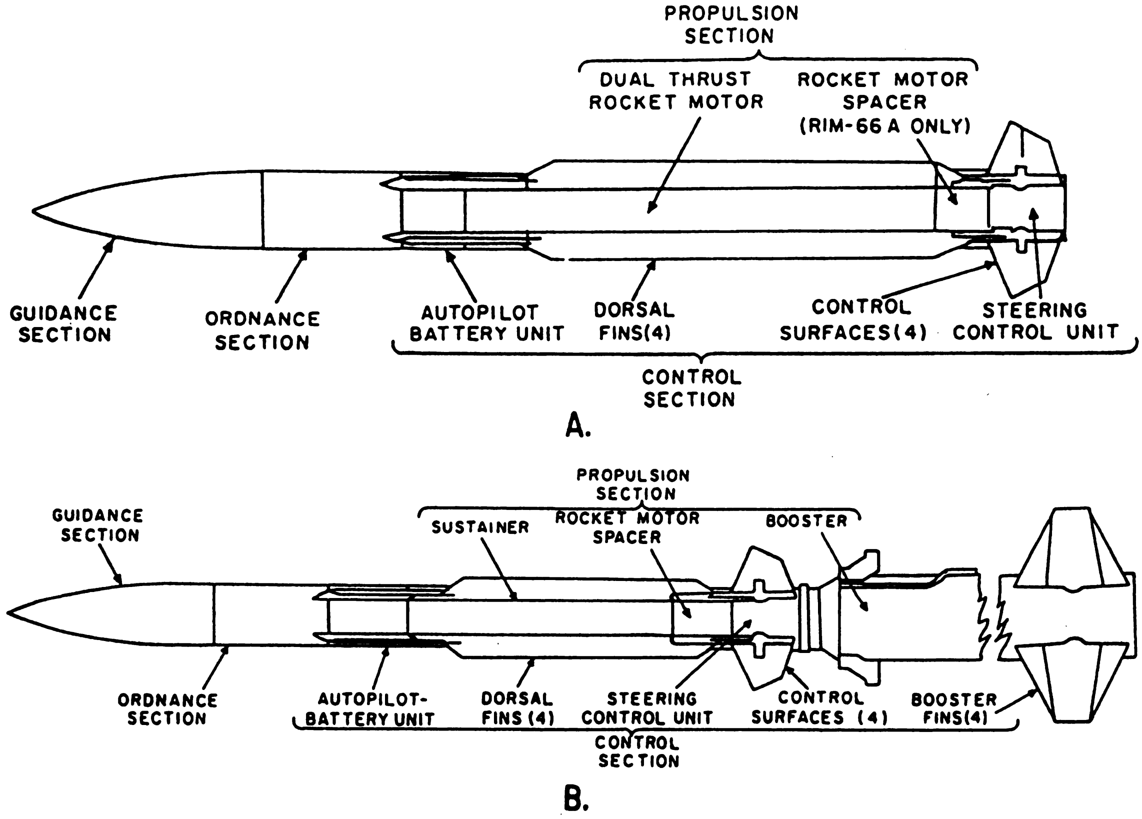

Figure 6-1.—Major sections and components of a Standard missile.

missile SM-1A (MR) with each of these components labeled.

GUIDANCE AND CONTROL

The guidance and control functions of a missile are often confused as being the same. A guidance system is used to keep the missile on its proper flight path—headed toward the target. The guidance system can best be described as the *brain* of the missile.

The control system, on the other hand, performs two functions. First, it maintains the missile in the proper flight attitude. Second, it responds to orders from the guidance system to steer the missile toward the target.

As you can see, the two systems are separate, but do work together.

Guidance

Generally, missile guidance is divided into three phases—boost, midcourse, and terminal. These names refer to the different time periods of missile trajectory (fig. 6-2).

BOOST.—The boost phase of missile flight is also known as the launch phase or initial phase. It is during this phase that the missile is boosted to flight speed. For **medium range** (MR) missiles that use a **dual-thrust rocket motor** (DTRM), the booster propellant grain is first consumed, then the sustainer motor takes over. For **extended range** (ER) missiles, the separate booster drops off at burnout, and the **sustainer** ignites to propel the missile. The sustainer functions to keep the missile at flight speed and moving toward the target.

MIDCOURSE.—The second, or midcourse phase of guidance is often the longest in both distance and time. During midcourse guidance, the missile makes any corrections necessary to stay on the desired course. The object of midcourse guidance is to place the missile near the target. Not all missiles use midcourse guidance; some use midcourse only to acquire the target.

TERMINAL.—The terminal phase brings the missile into contact or close proximity with the

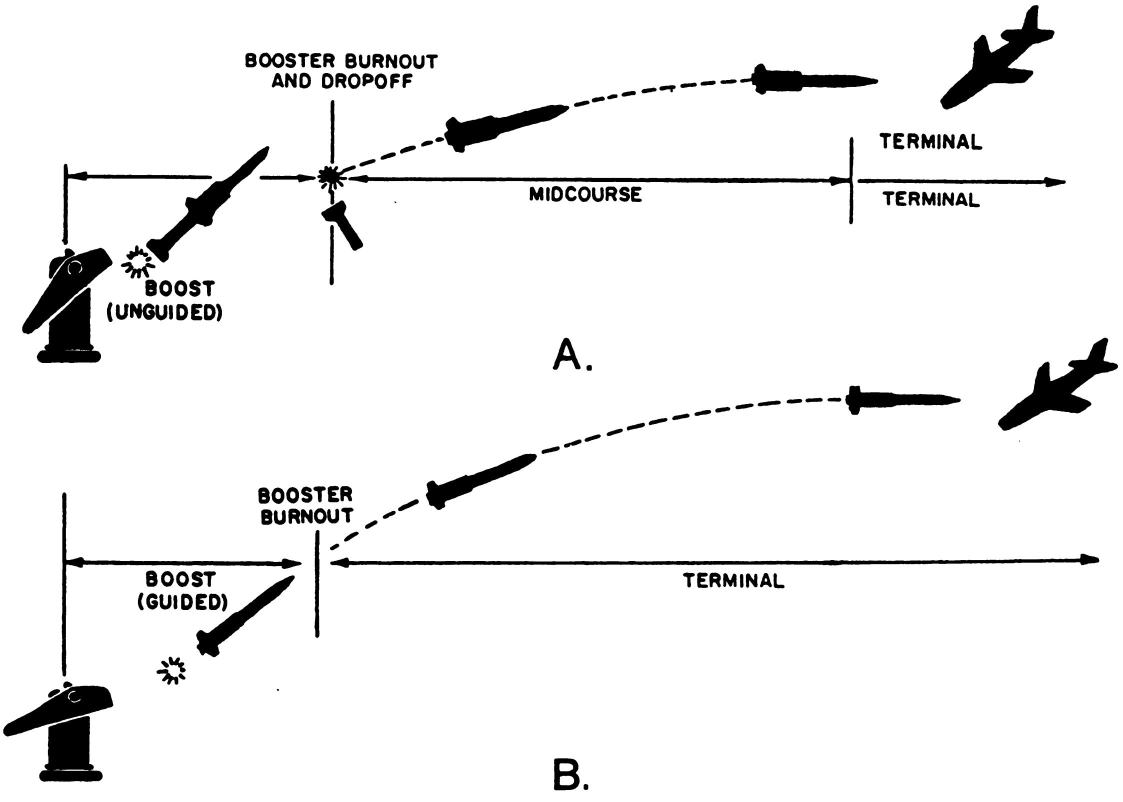

Figure 6-2.—Guidance phases of flight.

target. The last phase must have quick response to ensure a high degree of accuracy.

Types of Guidance Systems

There are three basic types of missile guidance systems in use: homing, inertial, and command.

HOMING GUIDANCE SYSTEMS.—Homing guidance systems rely on electronic radiations for guidance information. The homing device uses a small antenna in the nose of the missile. It detects radiation given off (or reflected) by the target. This information is converted into usable data, which is used to position the control surfaces to steer the missile. There are three types of missile homing systems used—active, semiactive, and passive.

Active.—In active homing guidance systems (fig. 6-3, view A), the missile contains a transmitter and receiver. The transmitter sends out radar signals in the general direction of the target. These signals are reflected by the target. The missile's receiver picks up the reflected signal and generates steering orders to bring the missile to an intercept with the target.

Semiactive.—In semiactive homing guidance systems (fig. 6-3, view B), the missile contains only a receiver (referred to as a seeker head or signal antenna). The ship's fire control radar serves as the transmitting source and directs its radar energy to illuminate the target. As with active homing, the reflected energy is received by the missile, which uses it to generate steering orders.

Passive.—Passive homing systems require the target to be a source of radiated energy (fig. 6-3, view C). Typical forms of energy used in passive homing are heat, light, and RF energy.

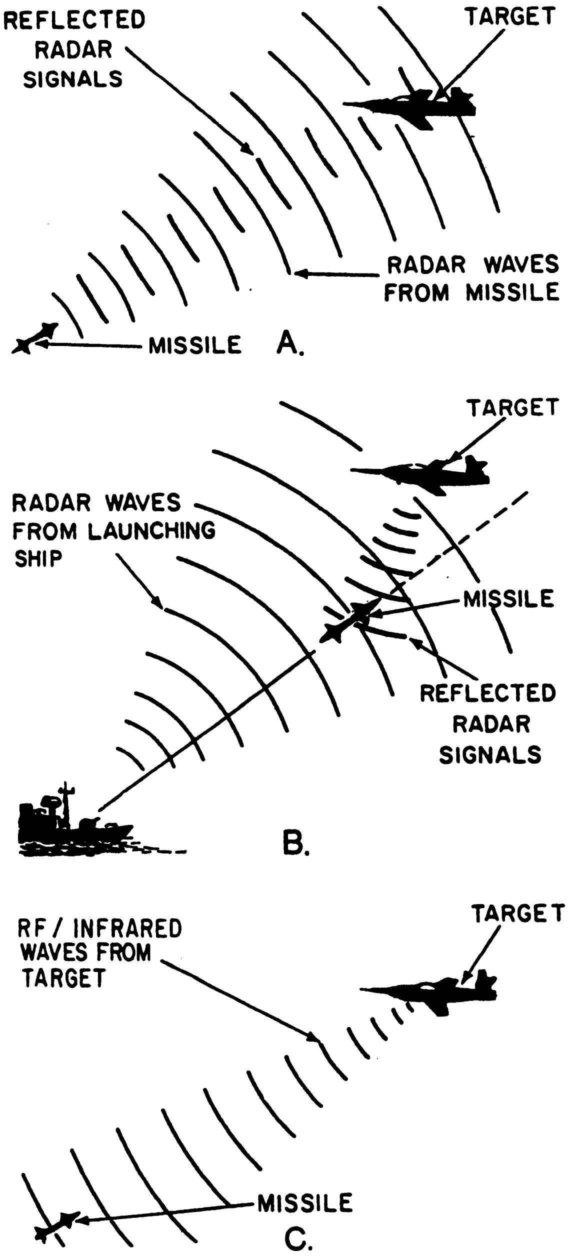

Figure 6-3.—A. Active homing; B. Semiactive homing; C. Passive homing.

INERTIAL GUIDANCE SYSTEMS.—An inertial guidance system is one that is designed to fly a predetermined path. The missile is controlled by self-contained automatic devices. These devices sense and measure accelerations or movements of the missile contrary to its programed path. These changes are translated to control surface orders, which correct the missile's flight. The major advantage of inertial guidance is that there are no existing countermeasures that can interfere with missile guidance. The Harpoon and Standard SM-2 missiles use this type of guidance during their midcourse phase.

COMMAND GUIDANCE SYSTEMS.—Command guidance means that the missile is controlled completely from an outside source. Commands including steering, arming, and detonation are all supplied to the missile via radar from the launching station. Command guidance is no longer used in the major missile systems now in the fleet.

Guidance Section Components

The guidance section of a Standard missile SM-1 (fig. 6-4) has three main components: the radome, two reference antennas, and the guidance assembly.

The radome structure consists of an aluminum shell and an RF transparent pyroceramic radome. It serves as the protective covering for the guidance unit and allows reception of the target signal. The two reference antennas are flush mounted in cutouts on the top and bottom of the guidance section.

The guidance assembly consists of a seeker head and the electronic package.

Control

To intercept and destroy a target, a guided missile must follow a desired flight path. This is the function of the control system. As stated earlier, the control system maintains the missiles flight attitude (keeps the top of the missile up and the bottom down). This is necessary to ensure that flight path corrections have the desired effect. If the missile were to be flying upside down, a correction to cause the missile to turn left would have the opposite effect, turning the missile to the right, etc.

Normally, control devices, preset before launch, are used to control missile stability. Flight path errors may be the result of incorrect initial computations, subsequent target maneuvers, natural forces or any combination of these. Signals from the guidance or control system are used as inputs to the control subsystem. The control subsystem is used to position the missile's control surfaces.

PROPULSION

The propulsion section provides the power or energy necessary to propel or move the missile to the target. As described earlier, the missile may use a separate booster rocket to get it up to speed before the sustainer takes over, or it may employ a dual-thrust rocket motor (DTRM). The DTRM (fig. 6-5) uses two different types of propellent grains. The slower burning sustainer propellent grains are first cast into the sustainer body, then the faster burning booster grains are cast over them. When the booster propellant completes burning, the sustainer propellant ignites.

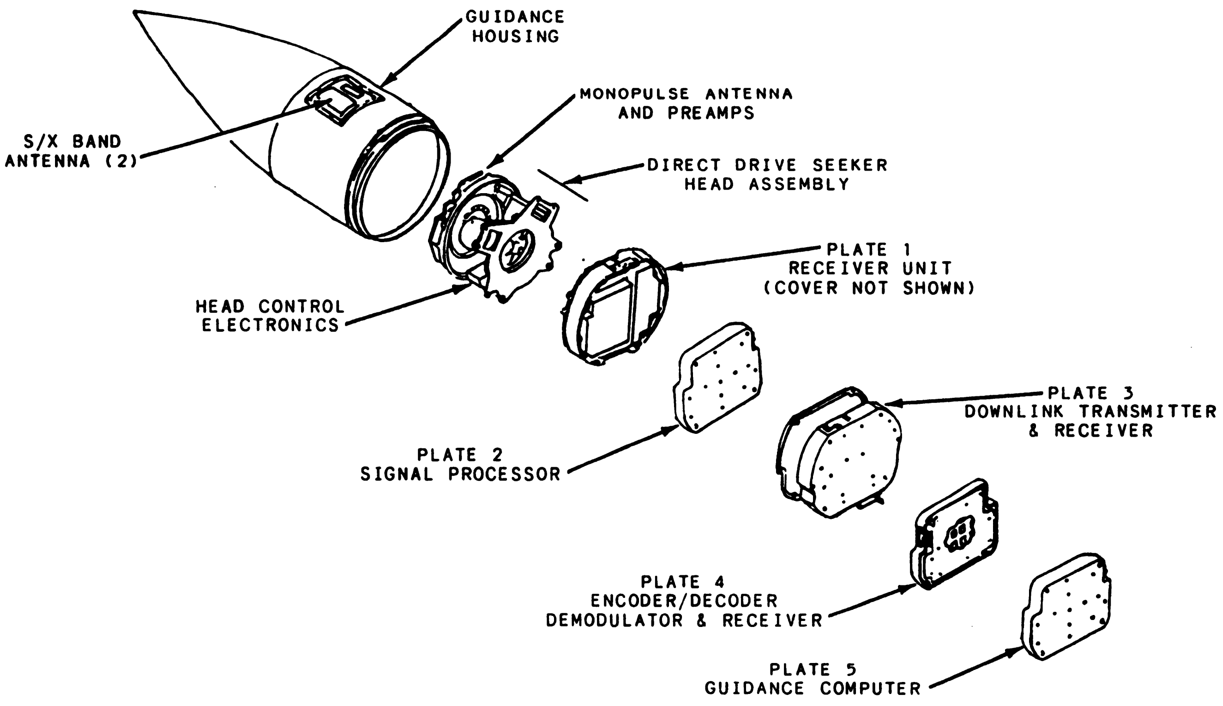
GUIDANCE HOUSING
MONOPULSE ANTENNA AND PREAMPS
S/X BAND ANTENNA (2)
DIRECT DRIVE SEEKER HEAD ASSEMBLY
PLATE 1 RECEIVER UNIT (COVER NOT SHOWN)
HEAD CONTROL ELECTRONICS
PLATE 3 DOWNLINK TRANSMITTER & RECEIVER
PLATE 2 SIGNAL PROCESSOR
PLATE 4 ENCODER/DECODER DEMODULATOR & RECEIVER
PLATE 5 GUIDANCE COMPUTER

Figure 6-4.—The missile guidance section (SM-2).

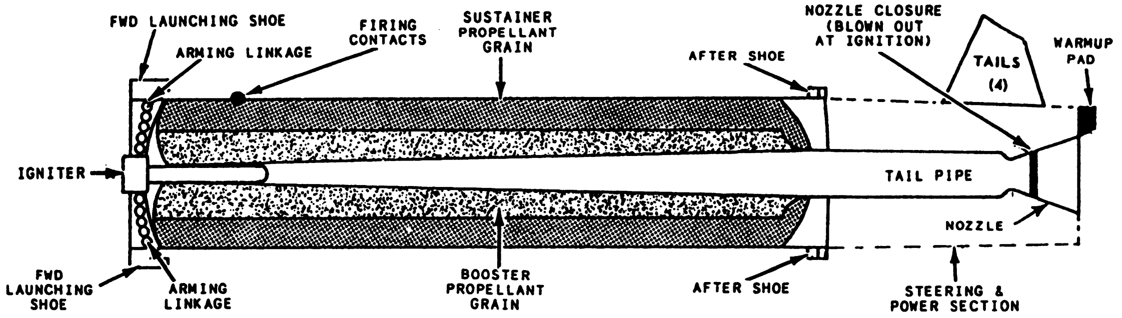

Figure 6-5.—A dual-thrust rocket motor.

Some missiles use a solid propellent, some a liquid propellent, and still others use both. In the later case, you will normally find the booster will use a solid fuel rocket motor, and the missile sustainer a liquid fuel rocket motor.

WARHEAD

Every action of the missile serves the sole purpose of delivering a payload on target. In exercise missiles, the payload usually includes telemetering units. The telemetering unit collects data on the missile's performance and transmits this data to receivers aboard ships and shore stations.

In the primary military role, the guided missile contains a destructive warhead and fuze. The basic warhead subsystem consists of three parts: a payload, a fuze, and a safety and arming (S&A) device.

Payload

The primary element of the warhead is the payload, which is the destructive agent (or other agent) used to accomplish the desired result. There are three types of destructive warheads common to guided missiles: blast-effect, fragmentation, and nuclear.

BLAST EFFECT.—This type of warhead causes damage by means of a high pressure wave or blast, which results from the detonation of high-explosive material.

FRAGMENTATION.—These warheads operate by bursting a metal case containing a high-explosive charge. Upon detonation, the container is shattered into hundreds of fragments that fly in all directions at high speeds. This type of warhead is very effective against air targets.

One variation of this warhead is the continuous-rod controlled fragmentation warhead. Upon detonation, the continuous-rod warhead expands radially into a ring pattern. The intent is to cause the connected rods to inflict damage during expansion (fig. 6-6).

NUCLEAR.—The nuclear warhead is used to destroy targets through the blast and shock waves produced by nuclear fission.

Fuzes

As described in earlier chapters, the fuze initiates detonation when the projectile passes near or strikes the target. As with gun projectile fuzes, there are several types of fuze, the most common being impact and proximity. Missile fuze descriptions are basically the same as those of gun projectiles (see descriptions in chapter 4).

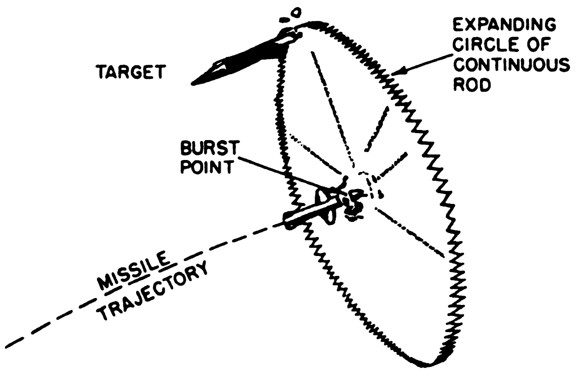

Figure 6-6.—Expansion of a continuous-rod warhead.

Safety and Arming

As with gun ammunition, it is desirable that missiles be physically prevented from detonating until they are a safe distance from the firing platform. Then, after the missile has reached a safe distance, it must be armed. The safety and arming (S&A) device performs both functions within the warhead. First, it prevents accidental detonation by interrupting the fuze train (safety). Secondly, it provides a firing path between the fuze and the payload (arming).

This concludes our discussion of the basic components that make up a guided missile. The remainder of this chapter will cover operational descriptions of the missiles currently in the fleet. Again, much of the information pertaining to guided missiles is classified and will not be presented here.

GUIDED MISSILE TYPES

In this section we will give a general functional description of the three missiles now in use aboard Navy surface combatants. These are the Standard (MR & ER), Harpoon, and Tomahawk missiles. Each of these missiles can be found in several variations because of the Navy's program of constantly upgrading missile capabilities. The specific performance data of each missile is available, on a need to know basis, through your ship's combat systems library.

STANDARD (MR & ER)

The Standard missile is the Navy's primary antiaircraft missile. It is launched from a variety of systems and is available in the medium range (MR) and extended range (ER) version. Both the MR and ER missile are available in the SM-1 and SM-2 models. As described earlier, the ER version has a separate booster. The SM-1 and SM-2 differences are not as visibly apparent. We will first describe the older SM-1. Pay particular attention to each missile's flight profile.

SM-1

The SM-1 missile uses both semiactive and passive homing guidance. Semiactive homing is the normal guidance mode during which the missile uses the ship's **continuous wave illumination** (CWI) FCS radar. The missile automatically shifts to passive guidance in an electronic countermeasures (ECM) environment.

The missile receives prelaunch information from the FCS computer while on the launcher. This information gives the missile the latest target tracking information. In flight, the guidance system directs the missile on a collision course to a predicted point in space. Ideally, the target and the missile arrive at this point simultaneously.

The SM-1 has three phases of guidance: boost, acquisition (midcourse), and homing (terminal). Figure 6-7 illustrates the guidance phases of the SM-1 missile.

BOOST.—During the boost phase, the ER missile flies an unguided ballistic trajectory, while the MR missile is both **roll stabilized** and guided. Roll stabilization places the missile on the proper flight attitude.

ACQUISITION.—The acquisition phase begins at boost phase termination. During this brief but important period, the missile seeks out and acquires the target.

Prelaunch information has programed the guidance assembly to position the signal antenna to look in the predicted direction of the target. The guidance assembly then scans the band of signals received to identify the reflected target signal. When the antenna locates the correct reflected energy, the missile has acquired the target.

Should the reflected signal become jammed or distorted, the missile automatically switches to passive mode homing. Upon acquisition of the

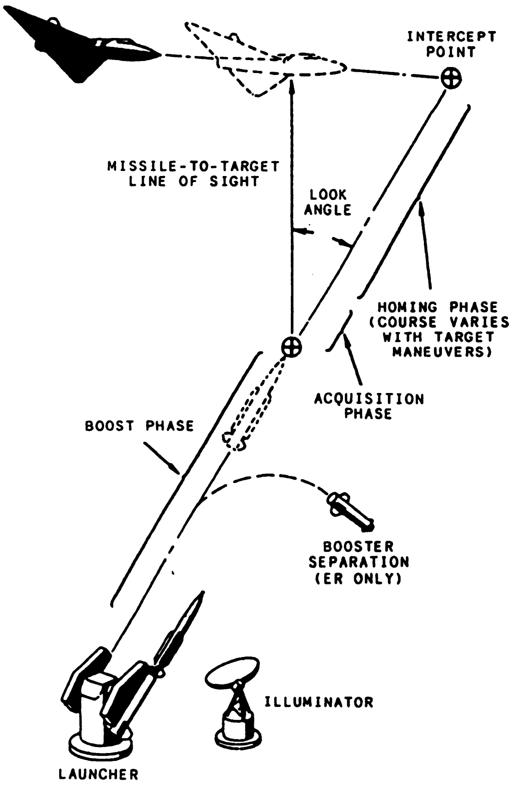
INTERCEPT POINT
MISSILE-TO-TARGET LINE OF SIGHT
LOOK ANGLE
HOMING PHASE (COURSE VARIES WITH TARGET MANEUVERS)
ACQUISITION PHASE
BOOST PHASE
BOOSTER SEPARATION (ER ONLY)
ILLUMINATOR
LAUNCHER

Figure 6-7.—Guidance phases of the SM-1 missile.

target, or initiation of the passive mode, the homing phase of guidance begins.

HOMING.—During the homing phase, the missile steers a collision course with the target. The homing phase continues until the warhead is detonated at target intercept. If the missile loses the target signal, it returns to the acquisition phase to search for the target. If the target is reacquired, homing begins again.

SELF-DESTRUCT.—The missile will self-destruct if either of two problems occur: first, if the missile fails to acquire the target in the given time; second, if the missile's internal electrical power fails. In either case, a self-generated signal activates the payload to cause detonation of the warhead.

SM-2

The SM-2 missile significantly increases the firepower potential of our missile firing ships. The SM-2 is similar in appearance to the SM-1 missile. The SM-2 (ER) uses the same airframe and propulsion system as the SM-1 (ER). The major difference between the two missiles, and the reason for the superior performance of the SM-2 is its guidance system. The SM-2 may use three types of guidance modes during its flight to the target: (1) inertial midcourse guidance with semiactive for terminal phase; (2) semiactive **home all-the-way** guidance (HAW); and (3) passive mode homing.

The inertial guidance feature of the SM-2 dramatically increases the missile's performance over the SM-1. When combined with the necessary modifications to the shipboard weapons system, the SM-2 offers several tactical advantages. A few examples are listed below.

- Due to its flight path, the SM-2 missile has greater effective range and terminal maneuverability than does the SM-1.
- The SM-2 can be launched in a quiet mode on search radar information alone, referred to as **launch on search** (LOS) mode. In the LOS mode, the FCS radar does not illuminate the target until the missile goes into the terminal semiactive homing phase. This frees the FCS directors, allowing several missiles to be launched and controlled at one time.
- The SM-1 missile requires a dedicated director throughout its entire flight, thus limiting the number of missiles in flight at any one time.

To better explain these advantages, we will now describe them as they occur in a typical SM-2 missile shot.

SM-2 Flight

Figure 6-8 illustrates the typical flight path of an SM-2 (ER) missile. Study and compare it with the SM-1 flight path shown in figure 6-7.

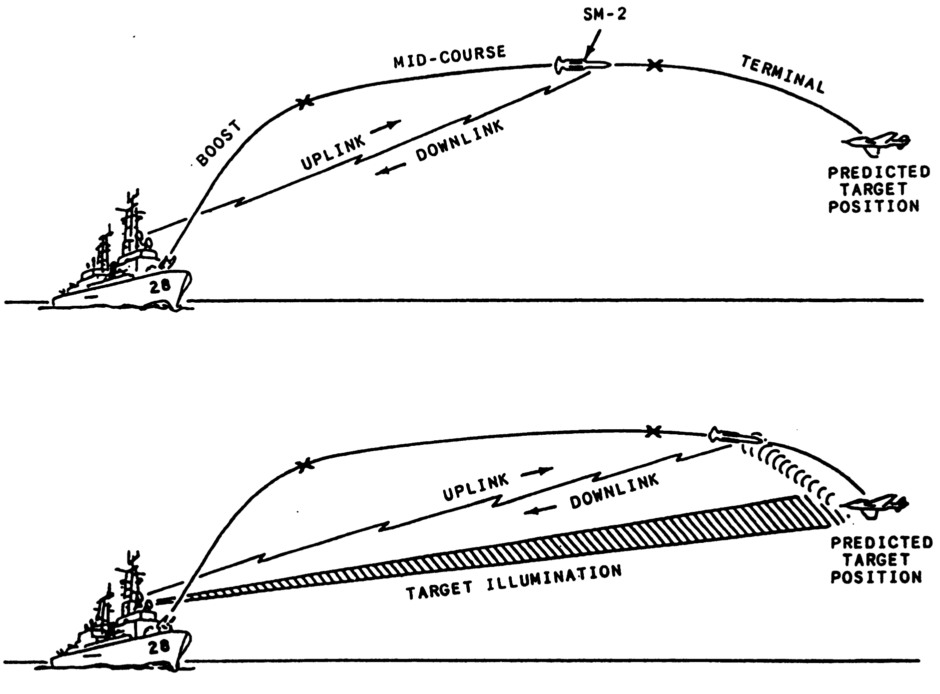

Figure 6-8.—Typical flight path of an SM-2 (ER) missile.

When launched, the SM-2 missile begins an up and over trajectory. This places the missile in a higher altitude early in the boost phase. The improved trajectory is precalculated by the FCS computer to fully exploit the potential of the propulsion system. As a result, the missile travels a midcourse trajectory where the lift-to-drag ratio is maximum.

During the midcourse phase, the missile uses an inertial reference unit to navigate to a predetermined point in space. Together with its own navigation data, the missile uses updated data from the launching ship. This information is transmitted on an uplink (ship-to-missile) and aids the weapon in computing proper intercept trajectory. Periodically, the missile transmits its onboard data to the ship on a downlink. This information aids the ship in evaluating the missile's progress. This process is used to instruct the missile to make course corrections. A different target could even be engaged, provided the course change was not too radical.

As the missile nears the target, the FCS illuminates the target with CWI. The terminal phase begins when the missile searches for and acquires the target. The missile is now in the semiactive homing mode and the reflected RF energy provides the source of guidance intelligence. The warhead's proximity fuze activates and initiates payload detonation as the missile closes on the target.

Figure 6-9 gives a range comparison of SM-1 (ER) and SM-2 (ER) missiles.

HARPOON

The Harpoon antiship missile is assembled in several configurations, which adapt it to air, submarine, and surface launch platforms. The surface-launched version, described in this section, is installed on a wide variety of ship classes. It can be launched either from a canister, an ASROC launcher, or certain GMLSs described in chapter 7.

The Harpoon is a subsonic, low altitude cruise missile for use against surface targets only. It is equipped with a self-contained midcourse (cruise) guidance system and uses advanced active homing techniques with countermeasure capabilities. Harpoon is designed as an all-up-round (AUR) for all weather fire and forget operations, and capable of engaging over-the-horizon targets.

Two views of a Harpoon missile are shown in figure 6-10. The missile is cylindrical in shape, with four fixed wings and four movable control fins. A booster is attached to the aft end of the missile and mounts four more fixed fins.

The Harpoon is assembled in six major sections:

1. Guidance
2. Warhead
3. Sustainer
4. Boattail
5. Booster
6. Control surfaces

Guidance Section

The guidance section structure houses four major components—seeker, radar altimeter, midcourse guidance unit, and a main power supply. Since the Harpoon is an active homing weapon, the seeker assembly performs a dual role—transmitting and receiving RF energy to illuminate and locate a target.

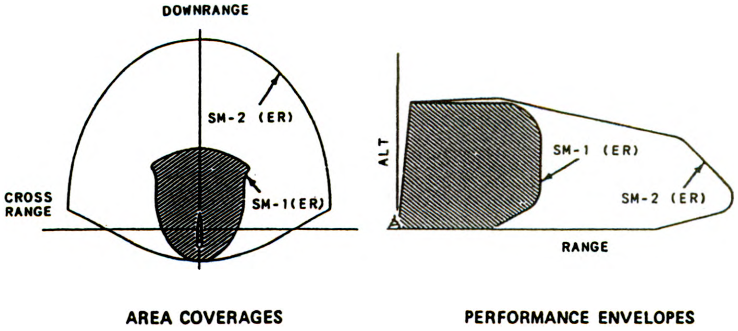

Figure 6-9.—Range comparisons of SM-1 (ER) and SM-2 (ER) missiles.

Warhead Section

The Harpoon missile uses a blast-type warhead. It is designed to remain intact until after ship penetration, then detonate for maximum effectiveness.

Sustainer Section

The sustainer section of the missile maintains flight speed after booster separation. Thrust is obtained from an air-breathing, liquid fuel, 600-lb thrust turbojet engine. The engine is located in the after part of the sustainer shell, with the fuel compartment in the forward section.

Boattail Section

The boattail section is a cylindrical aluminum shell tapered at its aft end. The main components of the boattail are four electromechanical control

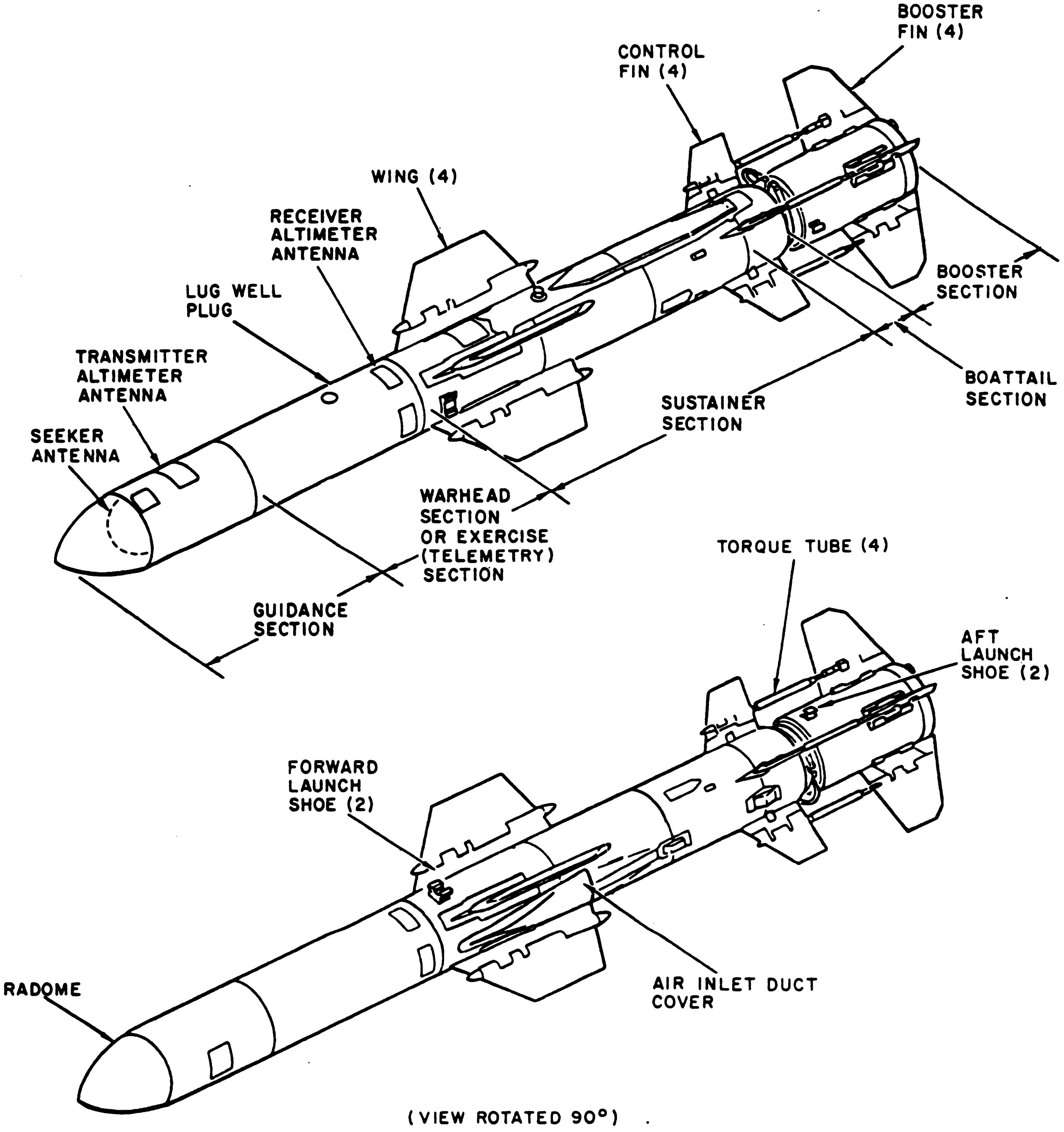

Figure 6-10.—Harpoon missile.

actuator assemblies. The actuators receive independent steering commands from the guidance section and position the four control surfaces through small electric motors.

Booster Section

The booster section attaches to the aft end of the boattail. The Harpoon missile, unlike the Standard missile, comes fully assembled with no mating/unmating required.

Control Surfaces

Aerodynamic lift and maneuvering of a Harpoon are accomplished by the following airfoils:

1. Four sustainer-mounted fixed wings
2. Four boattail-mounted movable control fins
3. Four booster-mounted fixed fins

The wings and fins are already installed on the missile when it is received. They are hinged and folded against the missile body during shipping and storage. They are unfolded prior to launch from a launcher, and upon launch from a canister.

Missile Flight

The following is a brief description of the general flight pattern of a Harpoon missile. There are several variations of the Harpoon currently in the fleet. Each version incorporates upgrades that improve the missile's performance and ECM defeating capabilities. These will not be discussed here since much of the information is classified.

Prior to launch, the missile is programed to search for targets at a certain bearing (bearing only launch or BOL) or bearing and range (range and bearing launch or RBL). The missile can be programed using information from the search radar. Because the missile is an active homing guidance weapon, it does not require the FCS to illuminate the target. Once launched, the missile is self-controlled (fire and forget).

Figure 6-11 illustrates the typical Harpoon missile profile. After booster separation, the missile descends to cruise altitude and steers a programed course. At a predetermined point, the guidance seeker activates and begins to search for a target. Once a target is acquired, the guidance computer generates steering orders for a target intercept.

As the missile closes on the target, it initiates (if programed to do so) the terminal maneuver and intercept phase. The missile first steers into a steep climb, then abruptly dives directly at the target. This allows the missile to penetrate deep into the target prior to detonation. This maneuver, as well as its low cruise altitude, makes the missile very difficult to defeat.

TOMAHAWK

The Tomahawk missile is a long-range cruise missile, with both land attack and antiship applications. It can be launched from air, surface, and subsurface platforms. The range capability of Tomahawk, with its high density fuel and turbofan engine, enables it to reach targets that previously could only be reached by ICBM.

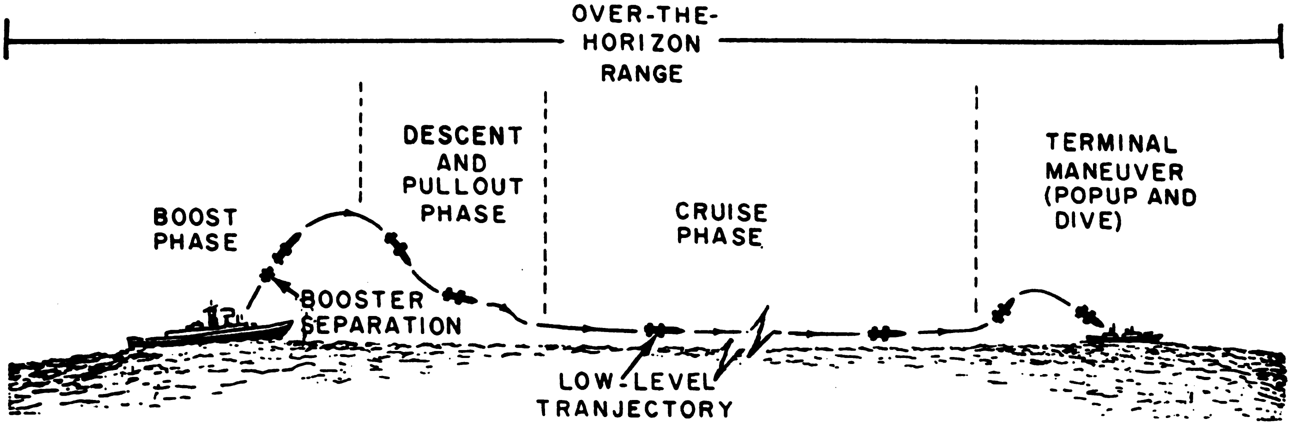

Figure 6-11.—Harpoon missile flight profile.

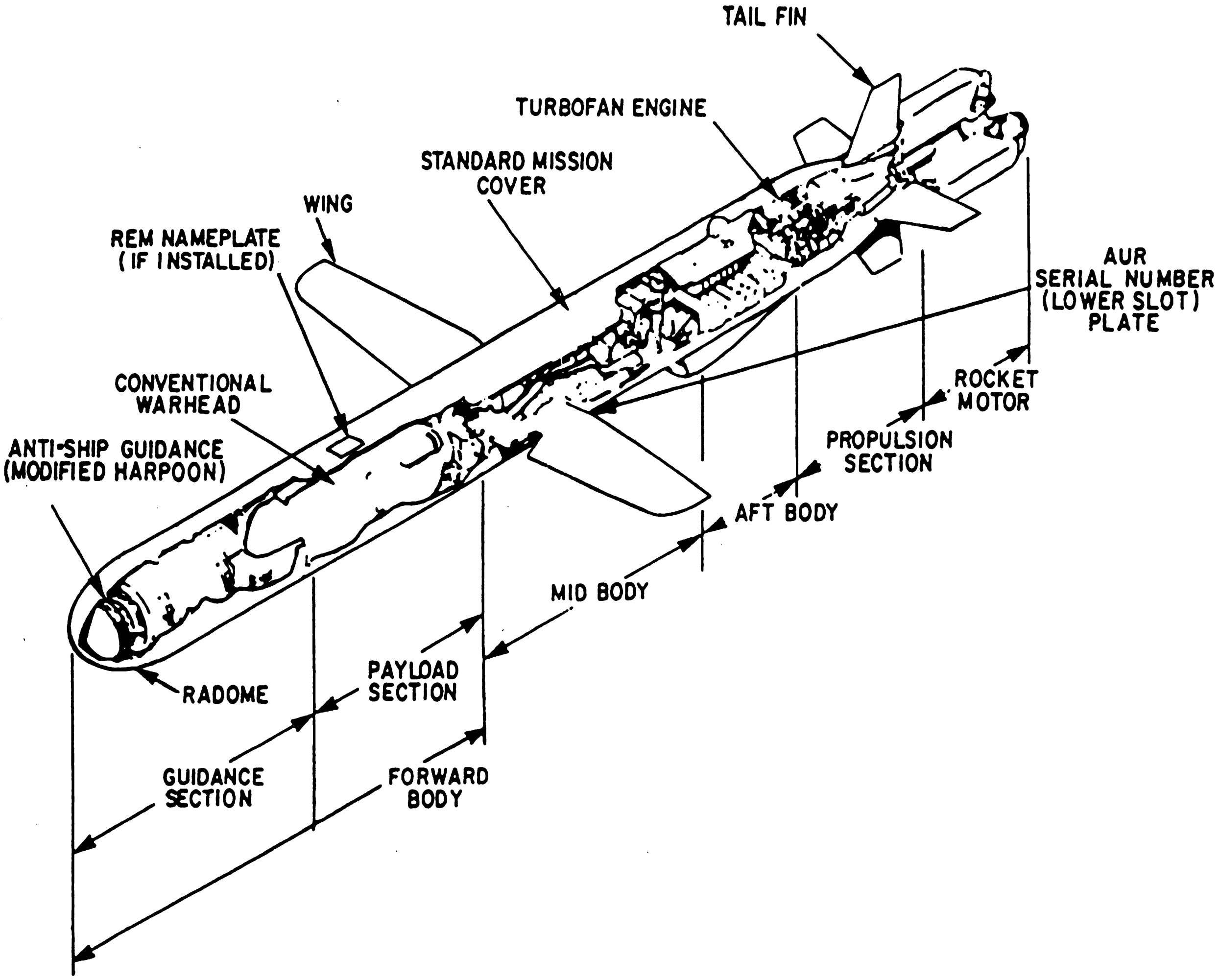

Figure 6-12.—Tomahawk missile (antiship) configuration.

The Tomahawk land-attack missile uses a terrain-matching guidance system, carries a nuclear warhead, and has a range of about 3,000 miles. The Tomahawk antiship missile (fig. 6-12) uses a modified Harpoon guidance system; but its range is only about 350 miles because of the heavier conventional warhead.

SUMMARY

This concludes the section on guided missiles. In this chapter, we have described the four sections of a modern guided missile—guidance, propulsion, control, and warhead. We have also briefly described the missiles currently in the fleet: Standard SM-1 and SM2, Harpoon, and Tomahawk. In the following chapter, we will describe the delivery units used to launch these missiles.

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GMM 3 & 2, NAVEDTRA 10188, Naval Education and Training Program Development Center, Pensacola, Fla., 1983.

The Weapons Officer, NAVEDTRA 10867-D Naval Education and Training Program Development Center, Pensacola, Fla., 1985.

CHAPTER 7

GUIDED MISSILE LAUNCHING SYSTEMS

The guided missiles described in the previous chapter receive prelaunch programing through, and are launched from, a delivery or launching system. The guided missile launching system (GMLS) performs the same basic function as a gun system. It is made up of the mechanisms necessary to store, load, position, and fire guided missiles. In first section of this chapter we will begin by describing the common major components of a GMLS. In the next section we will provide you with a functional description of the systems now in the fleet.

GMLS MAJOR COMPONENTS

A typical guided missile launching system consists of a magazine, loader, launcher, and dud jettison unit. These components may be independent subsystems with individual power drives, or they could all be incorporated into a single unit.

MISSILE MAGAZINES

A missile magazine is designed to provide a safe ready storage for guided missiles. A missile magazine may be configured to store missiles either vertically or horizontally. The storage configuration depends upon the type of launcher the magazine serves. The magazine, however, may also be the unit from which the missile is launched. This is the case with the surface-launched Tomahawk, the canister-launched Harpoon, and the Mk 41 Vertical Launch System (VLS).

Missile magazines are equipped with either a booster suppression or deluge system. These systems are designed to quickly extinguish the missile's rocket motor if it should accidentally ignite in the magazine. The missile magazine for the Mk 10 GMLS also has a dry-type sprinkler system.

LOADERS

Missile systems (where the magazine does not also function as the launcher) require a loading system to move the missile from the magazine to the launcher for firing. There are two such systems in use at the present, the Mk 10 GMLS and the Mk 13 GMLS.

LAUNCHERS

The launcher positions the missile for firing. This may or may not include a launcher capable of movement. You are probably most familiar with missile launchers that have a movable guide arm. Here the missile is loaded onto the rail—then trained and elevated to point toward the anticipated target intercept point. As missile technology advances, these types of launchers are becoming less necessary. Referring back to chapter 6, you will recall that only one of the missiles described, the Standard SM-1, requires prelaunch positioning. The wave of the future is the fixed-angle, canister-launched missile. The movable launcher however, will be with us for many years to come.

The launcher also serves as the unit through which the missile receives prelaunch programing from the fire control system.

DUD JETTISON UNIT

In the event of missile failure, and especially if the missile catches on fire, it is necessary to eject the missile from the launcher into the sea. This is the function of the dud jettison unit.

LAUNCHING SYSTEMS

In this section we will describe the launching systems currently in the fleet. These include the movable Mk 10, Mk 13, and Mk 26 GMLSs, and the fixed angle Mk 41 Vertical Launch System (VLS), Harpoon, and Tomahawk GMLSs.

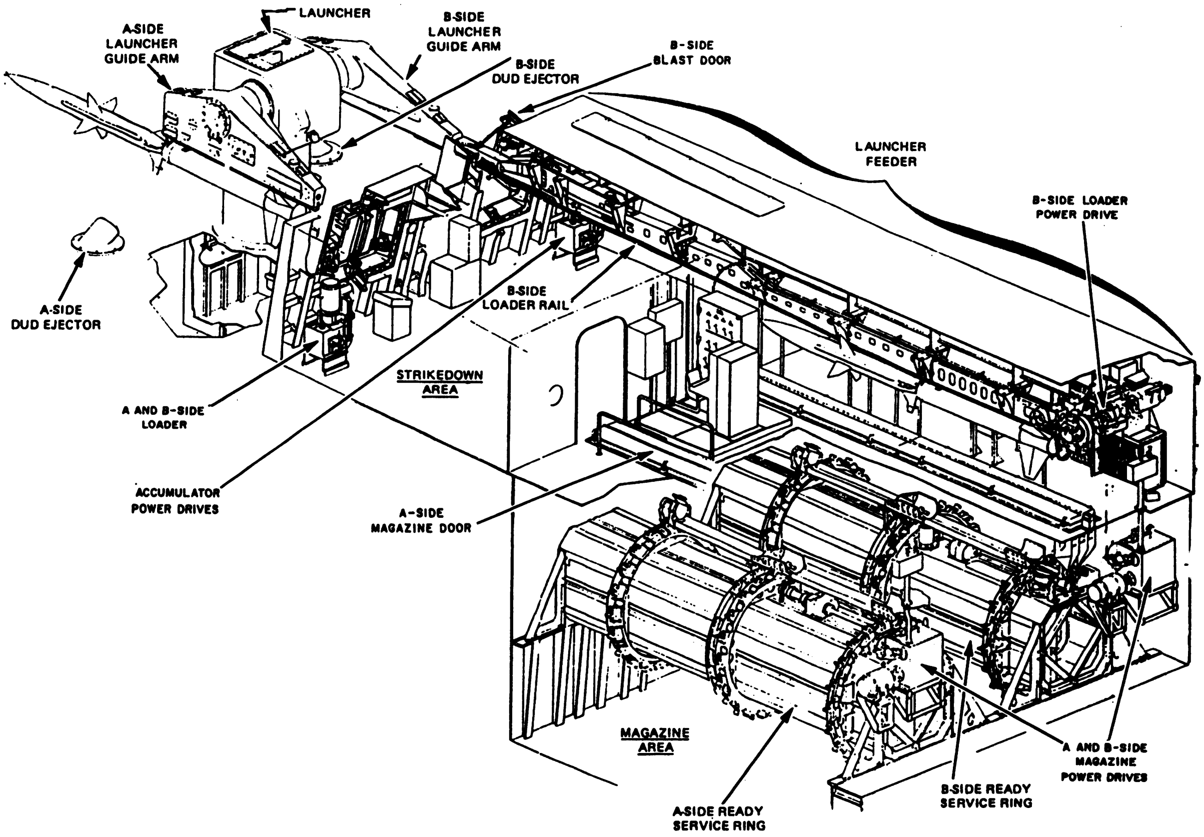


Figure 7-1.—The Mk 10 GMLS (Mod 0 configuration).

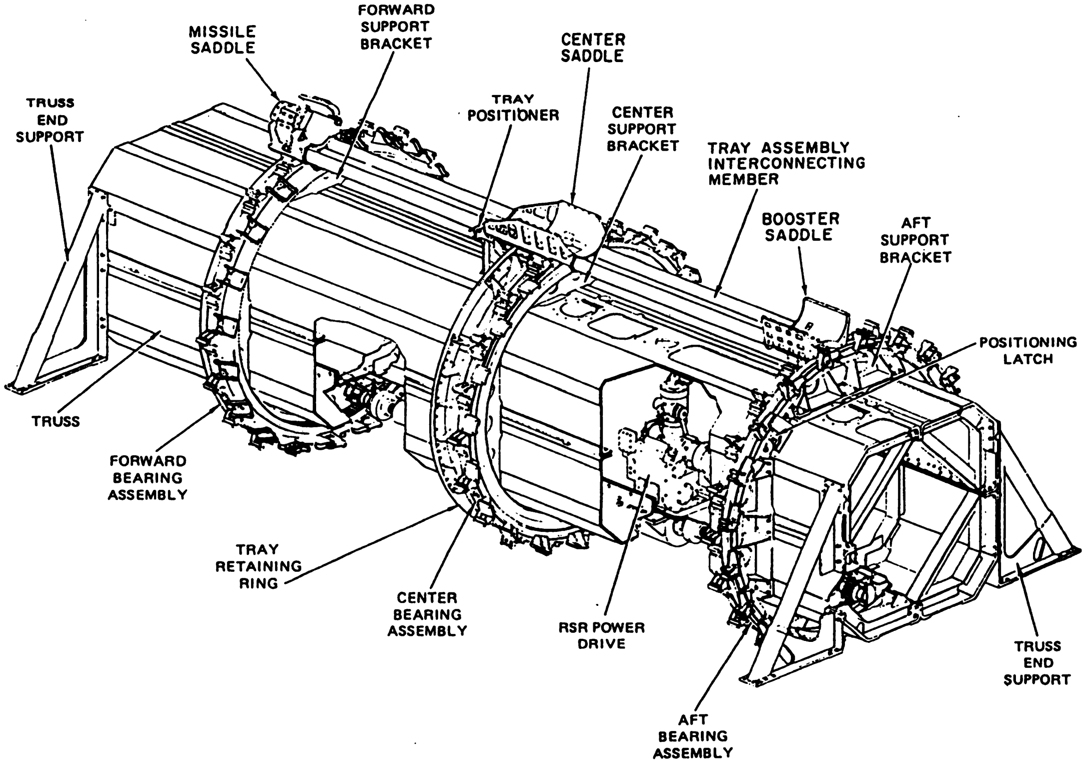


Figure 7-2.—Ready service ring.

Mk 10 GMLS

Designed to fire the Standard (ER) Missile, the Mk 10 GMLS (fig. 7-1) is a two-sided system composed of an A-side and a B-side that are identical mirror images of each other. Each side is a totally independent system, consisting of four basic component groups: a launcher feeder, a launcher, a dud jettisoning unit, and system control units/panels.

Launcher Feeder

The launcher feeder system contains the components that stow missiles, provide facilities for assembly and disassembly of missile control surfaces, and deliver missiles to the launcher.

Located directly below the missile assembly area, the missile magazine contains the **ready service rings** (RSRs), which horizontally store 20 missiles each (fig. 7-2). When loading orders are received, the desired missile is indexed to the hoist position, RSR station one (fig. 7-3).

Directly above the hoisting station in the assembly area deck is the magazine door

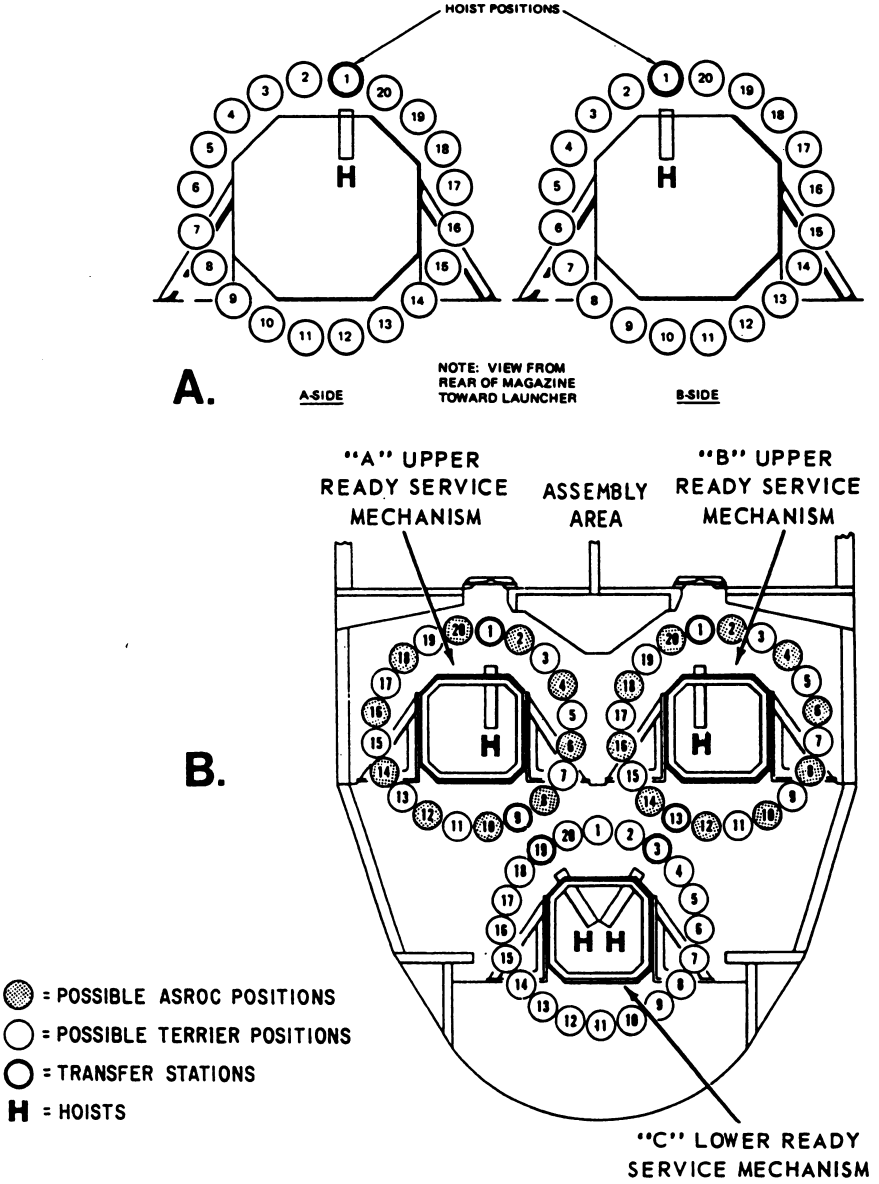

HOIST POSITIONS
H
A.
A-SIDE
NOTE: VIEW FROM REAR OF MAGAZINE TOWARD LAUNCHER
B-SIDE
"A" UPPER READY SERVICE MECHANISM
ASSEMBLY AREA
"B" UPPER READY SERVICE MECHANISM
B.
H H
"C" LOWER READY SERVICE MECHANISM
= POSSIBLE ASROC POSITIONS
= POSSIBLE TERRIER POSITIONS
= TRANSFER STATIONS
H = HOISTS

Figure 7-3.—RSR stations and hoist positions.

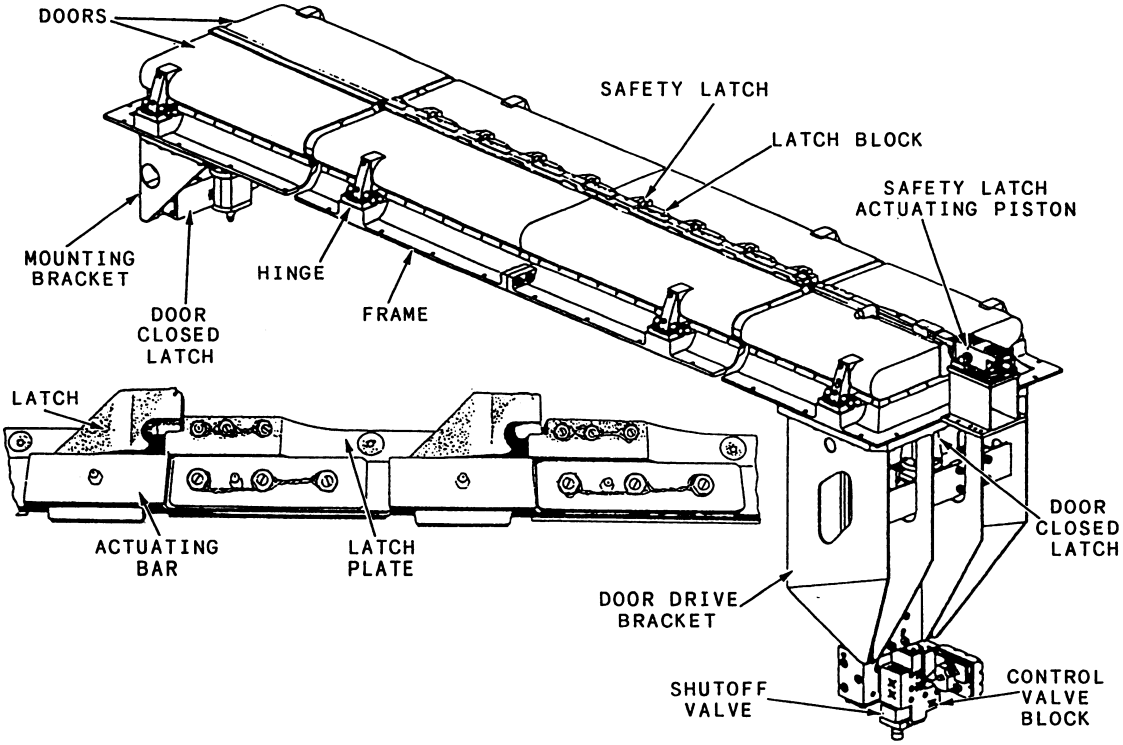


Figure 7-4.—Magazine door assembly.

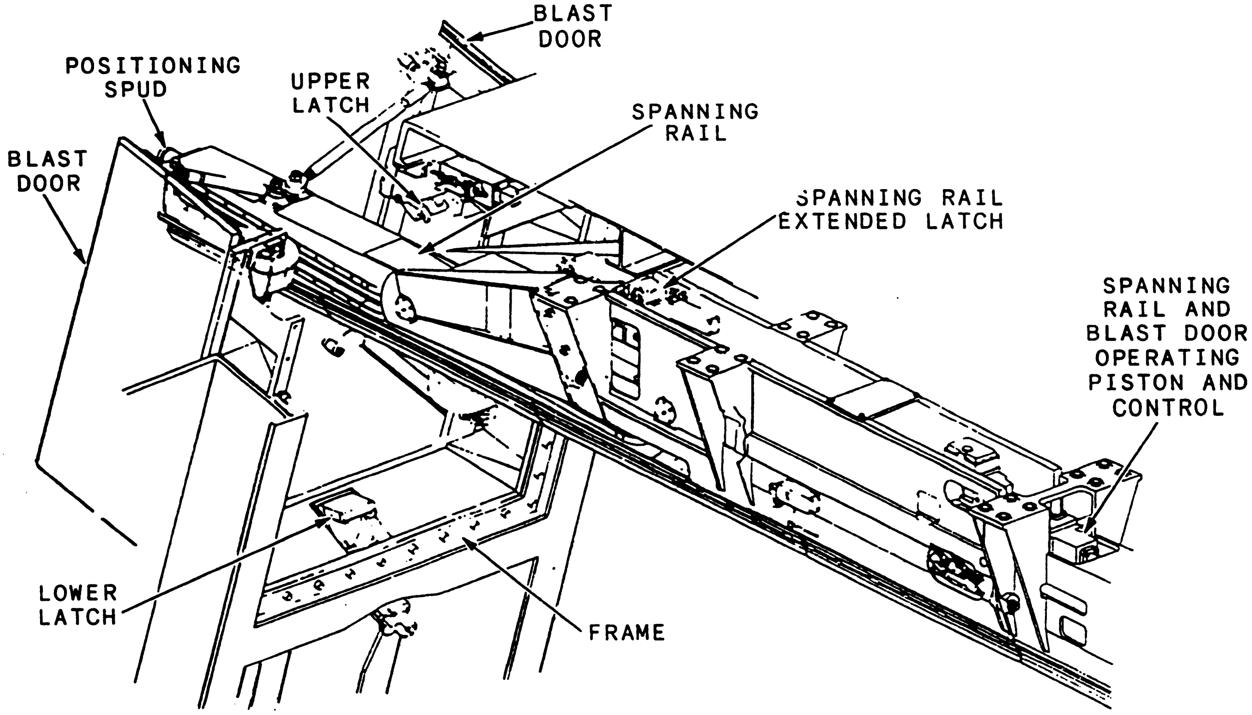

BLAST DOOR
POSITIONING SPUD
UPPER LATCH
SPANNING RAIL
BLAST DOOR
SPANNING RAIL EXTENDED LATCH
SPANNING RAIL AND BLAST DOOR OPERATING PISTON AND CONTROL
LOWER LATCH
FRAME

Figure 7-5.—Spanning rail and blast doors assembly.

(fig. 7-4). When the desired missile is in the hoisting position, this door is opened and the missile is hoisted up into the assembly area and placed on the loader rail. While on the loader rail, the missile wings are folded out and the booster fins are installed manually by the crewmen stationed there.

When the wing and fin operation is complete, each wing and fin man steps on a safety switch indicating that his job is complete and that he is clear of the missile. At this time the blast doors open and the span rail extends to bridge the gap between the loader rail and the launcher guide arm rail (fig. 7-5). The loader mechanism then moves the missile along the loader rail through the blast doors and onto the launcher guide arm. Once the missile is latched into place on the launcher, the span rail retracts and the blast doors close.

Launcher

The launcher receives missiles from the feeder system, prepares them for firing, trains, and elevates them to the firing position from which they are launched. The launcher consists of the following components:

1. Stand
2. Carriage
3. Guide and Power Drive
4. Train and Elevation Systems
5. Slipring

STAND.—The stand (fig. 7-6) is a cylindrical structure that extends from about 2 feet below the

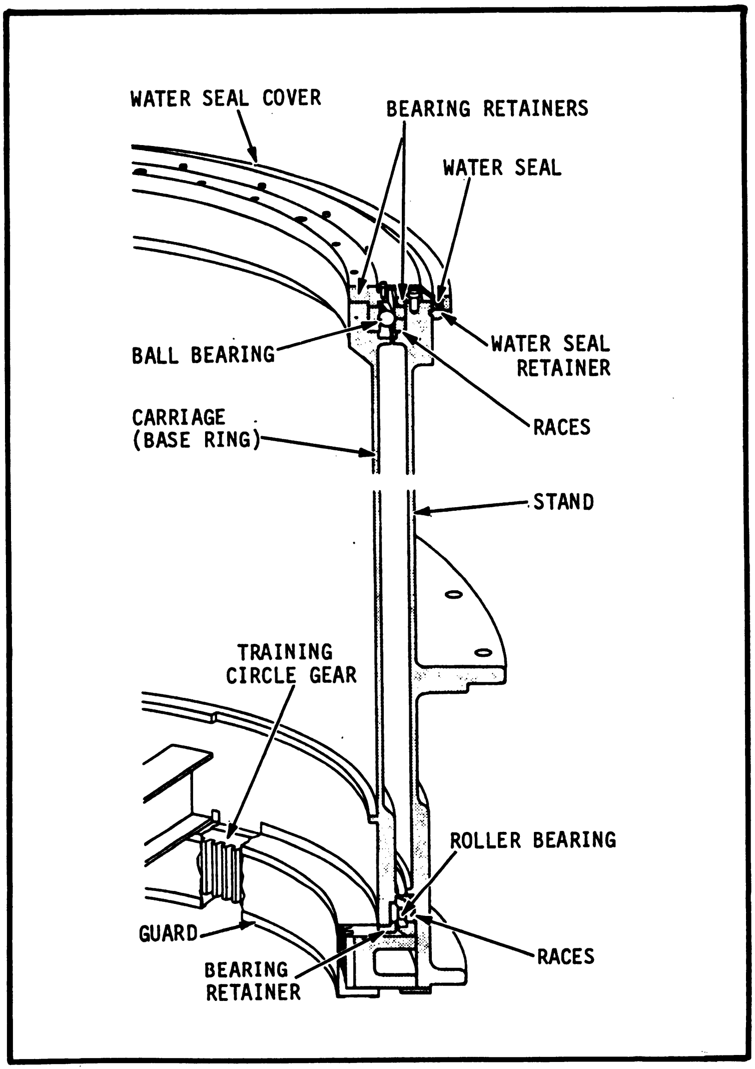


Figure 7-6.—Stand and train bearings.

weather deck to a height of 9 feet. It is stationary, flange mounted to the deck, and functions to support the carriage and guide arms.

The train bearings are mounted in races at the top and bottom of the stand, which permit the carriage to rotate within the structure. The bearings at the top of the stand support the weight of the carriage, while the lower bearings hold the carriage in concentric alignment.

CARRIAGE.—The carriage structure (fig. 7-7) is mounted within and extends above the stand. It consists of two general areas that support the guide and house the train and elevation systems as well as the slipring.

GUIDE AND POWER DRIVE.—A guide arm (fig. 7-8) is mounted at each end of the trunnion tube. The guide arm supports the missile, connects all external electrical circuitry to the missile (including the firing circuit), arms the booster, and releases the missile.

The guide arm power drive is located inside the trunnion support on the right side. It is an accumulator-type power drive that supplies hydraulic fluid under pressure to operate all the components in the guide arms.

Once on the launcher, the missile is held in place by both the aft shoe latch and the forward restraining latch. The booster connector now extends to cover the boosters contactor pad and penetrate it with 19 contact pins. The missile receives its preflight information through these pins. At the same time the arming device extends to arm the booster. Both the booster contactor and the arming device remain extended until just prior to launch.

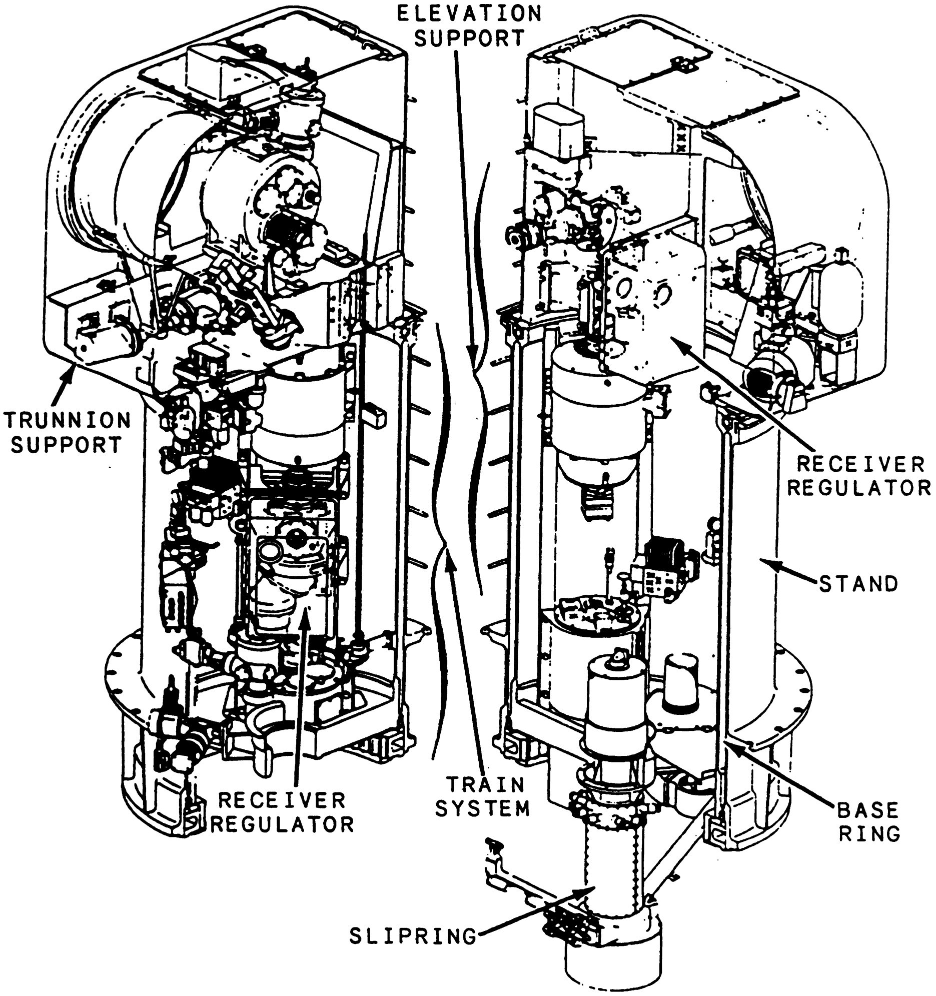


Figure 7-7.—Carriage structure.

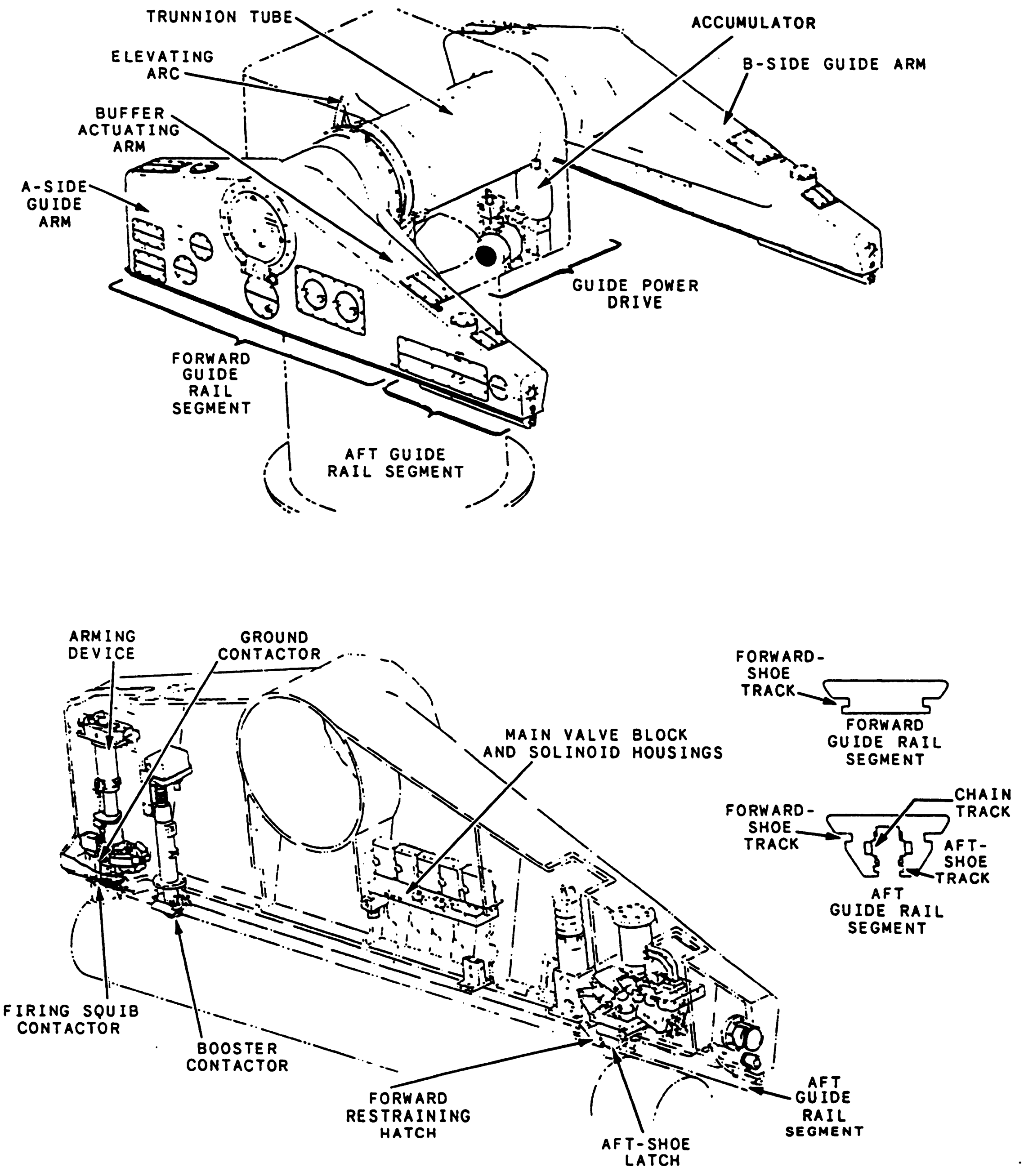


Figure 7-8.—Guide arm components.

The firing squib contactors and ground contactors are forward of the arming device. The firing squib contactors provide an electrical connection point for the firing circuit between the launcher and the booster. The ground contactors touch the top of the forward booster shoe, providing an electrical ground. The firing squib contactors touch both sides of the forward booster shoe.

TRAIN AND ELEVATION SYSTEMS.—The train and elevation systems control the velocity, acceleration, deceleration, and positioning of the launcher. Except for the amplifier assembly, all of the train system components are located inside the carriage base ring. The elevation components are in both the trunnion support and base ring areas.

Since the functioning of power drives was covered in an earlier chapter, they will not be covered again here.

SLIPRING.—The slipring is located in the carriage and serves to transfer electrical power and anti-icing fluid between the stationary and rotating components of the launcher.

Dud Jettison Unit

The Mk 10 GMLS has a dud ejector mounted on each side of the launcher (fig. 7-9) on the weather deck. The ejector control panel is located inside the missile house.

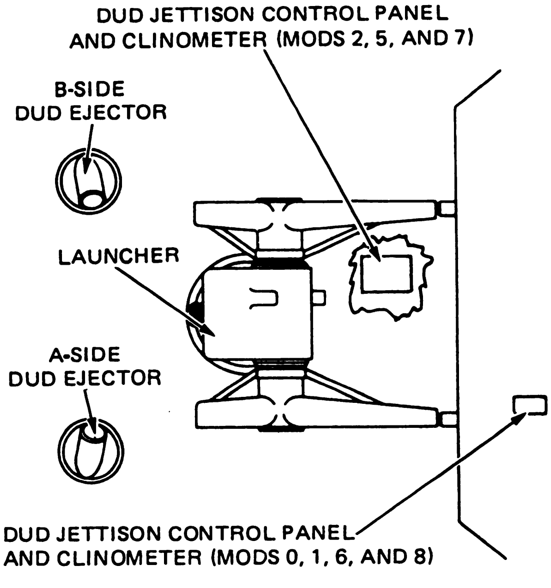

DUD JETTISON CONTROL PANEL AND CLINOMETER (MODS 2, 5, AND 7)
B-SIDE DUD EJECTOR
LAUNCHER
A-SIDE DUD EJECTOR
DUD JETTISON CONTROL PANEL AND CLINOMETER (MODS 0, 1, 6, AND 8)

Figure 7-9.—Dud Jettison Unit configuration.

When it is determined that a dud missile must be jettisoned, the launcher captain positions the launcher to eject from the side the dud is on. LP air then extends the ejector piston sleeve (fig. 7-10). This places the ejector pan, which is attached to the end of the ejector piston, in close proximity to the base of the missile booster. HP air against the piston head extends the ejector with sufficient force to eject the missile from the guide arm into the sea.

Control Panels

Figure 7-11 illustrates the location of the control panels used to operate the Mk 10 GMLS.

POWER PANEL EP1.—The EP1 panel distributes power to the systems drive motors and contains circuit breakers for each motor circuit.

CONTROL PANEL EP2.—The EP2 panel contains the electrical control circuits and indicators used to monitor and control GMLS operation. This panel is manned by the launcher captain.

TEST PANEL EP3.—The EP3 panel contains the electrical circuits used to test the launcher train and elevation systems.

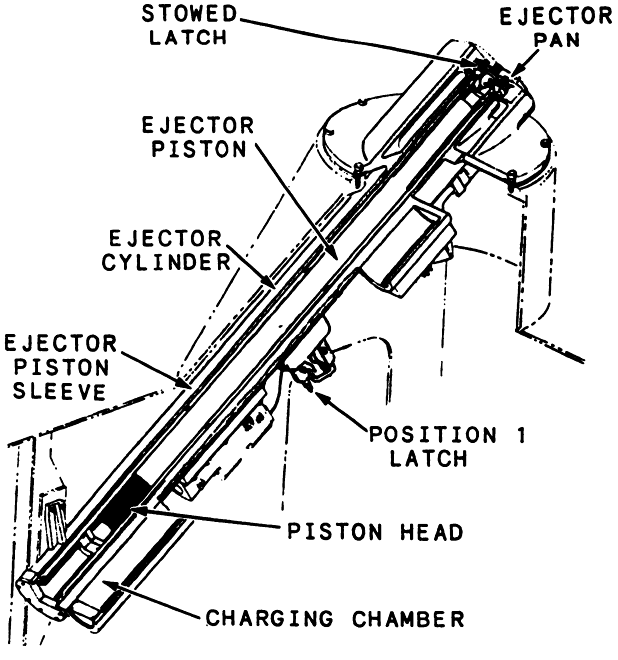
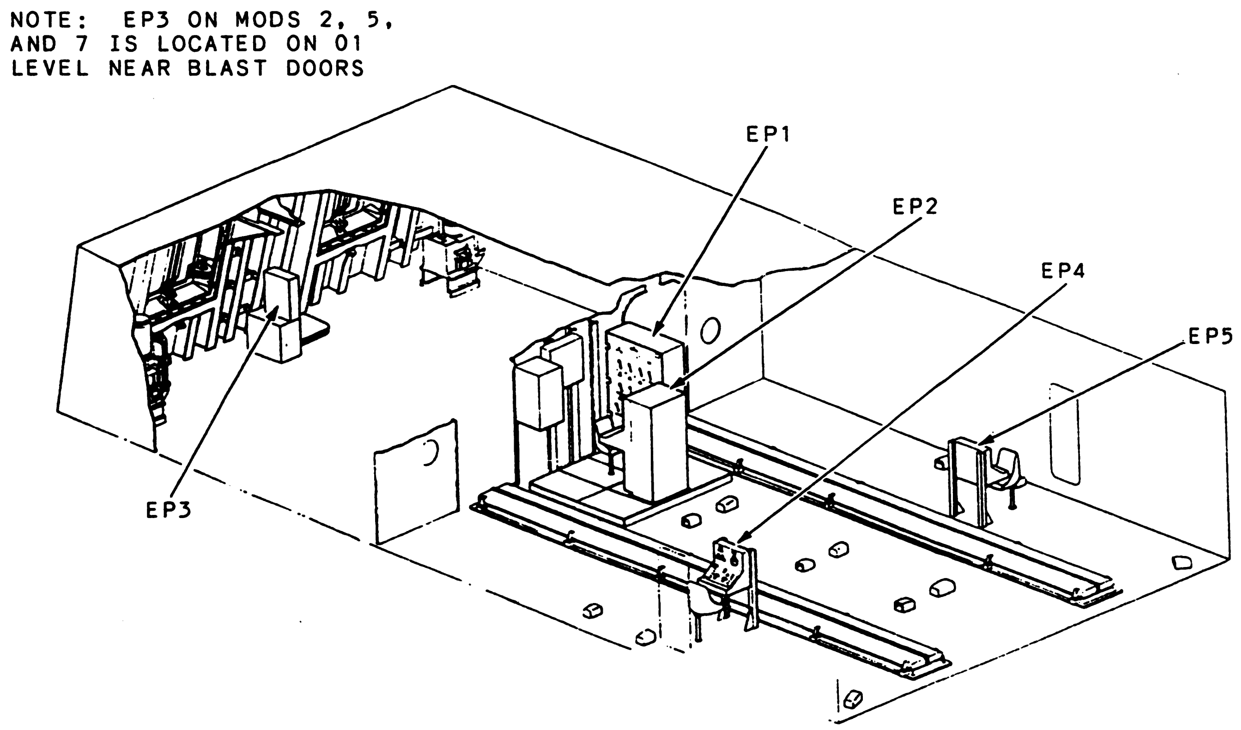


Figure 7-10.—Dud ejector.



NOTE: EP3 ON MODS 2, 5, AND 7 IS LOCATED ON 01 LEVEL NEAR BLAST DOORS

Figure 7-11.—System control panels.

CONTROL PANELS EP4 AND EP5.— These panels contain the electrical circuits used to control and monitor missile assembly, unload, strikedown, and checkout operations. The EP4 panel controls the A-side and the EP5 panel controls the B-side.

MOD DIFFERENCES

The major MOD differences that will be encountered involve the number of RSRs, the addition of a tilt rail, and the ability to fire ASROC. Of these differences, the most notable is the addition of a tilt rail.

The tilt rail is used on launchers that are located on the ship's forecastle. The missile house for these launchers is located below the ship's main deck (fig. 7-12); the launcher is located above on the main deck. This requires the missiles to be loaded on to the launcher at an angle.

In this configuration, the loader rail is also the tilt rail. As in the aft launcher configuration, the loader rail receives the missile from the RSR. Once the missile is assembled for flight, the loader rail then "tilts," becoming the tilt rail, to mate with the stationary span of the loader rail that is angled up toward the blast doors and the launcher.

At this writing, all Mk 10 systems are in the process of being upgraded with solid state control circuitry.

Mk 13 GMLS

The Mk 13 GMLS (fig. 7-13) is commonly known as the "One-Armed Bandit." It is designed to stow, load, aim, and launch the SM-1 Standard (MR) and Harpoon missiles. The system is physically capable of firing the SM-2 (MR) missile, but is normally limited to firing the SM-1 because of the shorter range capability of its

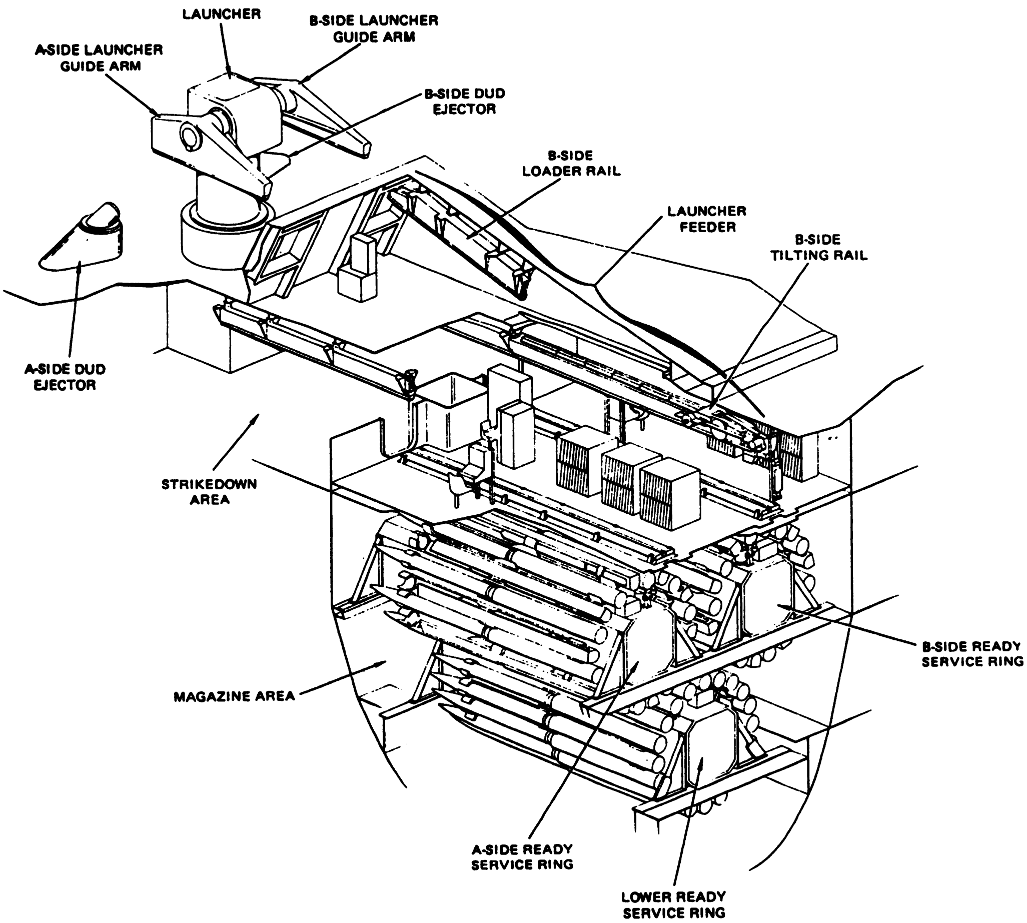


Figure 7-12.—Mk 10 GMLS forward launcher.

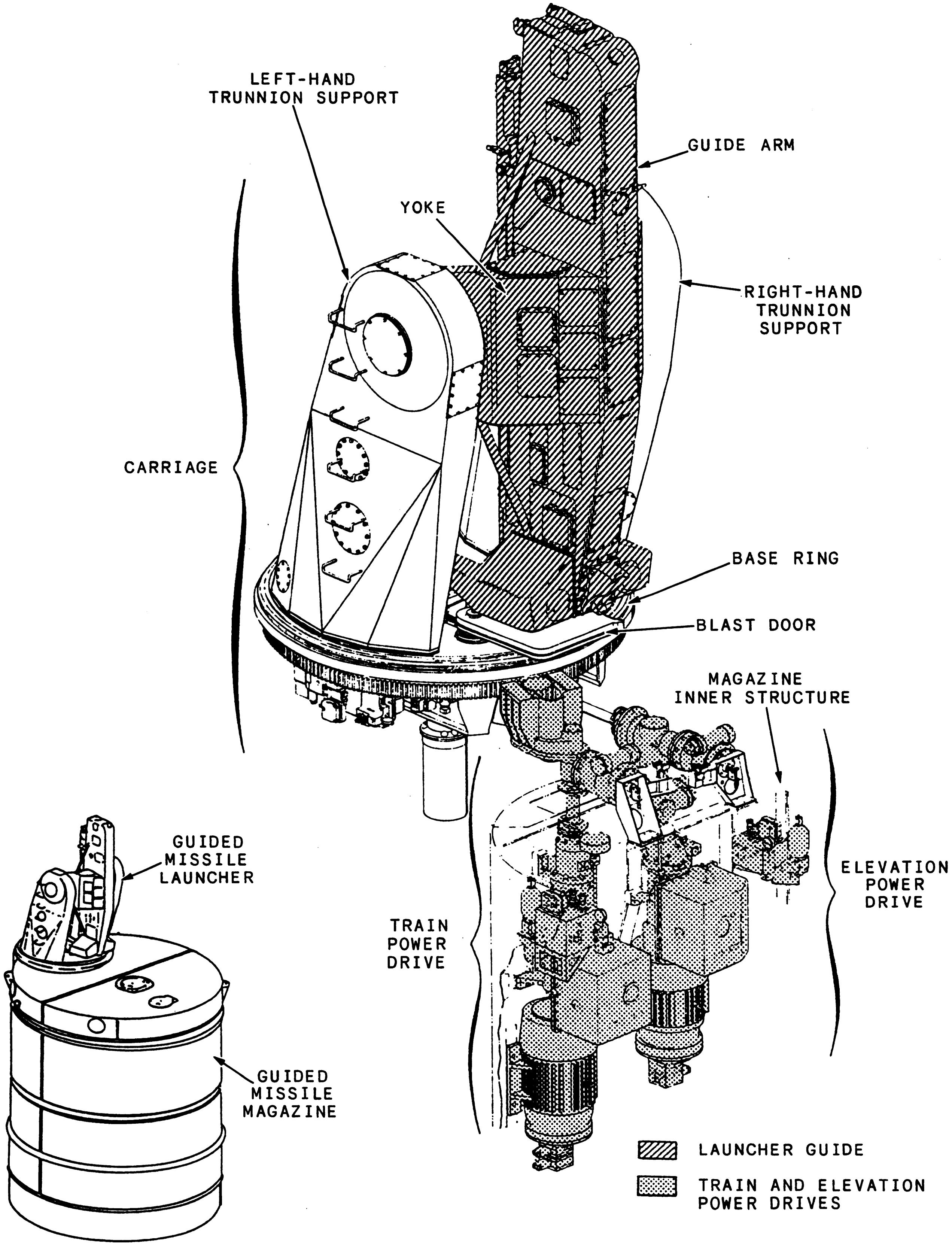


Figure 7-13.—The Mk 13 Mod 4 GMLS.

associated fire control system. Future upgrades may allow for the full use of the SM-2's greater range, making the Mk 13 a more versatile launch platform. There have been several different versions in use over the years, but most have been (or will be) converted to the Mod 4. Therefore, all descriptions given here are those of the Mk 13 Mod 4 GMLS.

Unique to the Mod 4 system is the fact that, if properly set up, the FCS/WCS can remotely light off the launching system, load, and fire a missile.

The Mk 13 GMLS consists of a magazine, launcher, and system control units.

Magazine

The guided missile magazine is a stationary, unmanned, cylindrical structure, which vertically

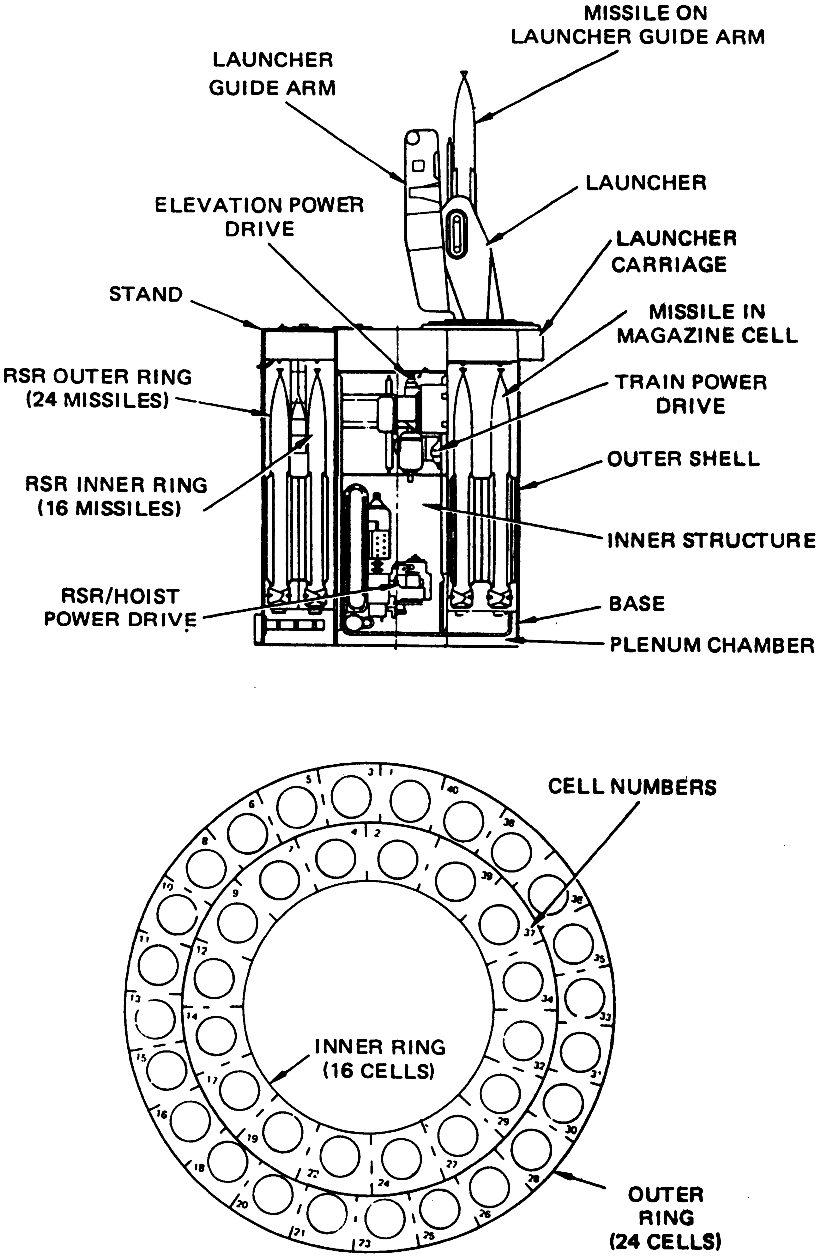


Figure 7-14.—Magazine general arrangement.

stores the missiles and supports the launcher. Located in the magazine is the RSR and the hoist.

The RSR (fig. 7-14) is a rotatable drum-like structure with two rings containing 40 cells. Each cell is equipped with a rail to support one missile. The bottom surface of the RSR has 40 openings. Each opening is equipped with a blow-in plate. Also arranged in the bottom of the RSR are 96 water injection nozzles to cover every indexed position of the RSR.

If a missile ignites in the magazine, the blow-in plate collapses, providing an opening to the **plenum chamber**, which vents the exhaust gases to the atmosphere. In addition to the water injection nozzles, the magazine contains water sprinkling and CO_2 flooding systems, which are automatically activated by heat sensing devices.

The hoist assembly moves missiles from the magazine to the launcher for loading operations, and from the launcher to the magazine for unloading operations. There are two hoist pawls, one for each ring of missiles. The pawls operate separately, but are driven by the same unit. A shifter assembly engages the hoist chain to the proper pawl to load from either the inner or outer ring of missiles.

A retractable span rail is just above the RSR. This rail extends during load and unload operations to bridge the gap between the rail in the RSR and the rail on the launcher guide arm.

Launcher

The guided missile launcher is a single-arm launcher that receives missiles from either of the stowage rings located in the magazine. The launcher has two load positions, one for each ring (fig. 7-15).

The major components of the launcher include a carriage, guide arm, and train and elevation power drives.

The structural units of the carriage are a base ring and two trunnion supports. A blast door is part of the base ring. The blast door provides a blast proof, water proof seal over the opening through which missiles move between the magazine and the launcher. The two trunnion supports of the carriage straddle and support the guide arm.

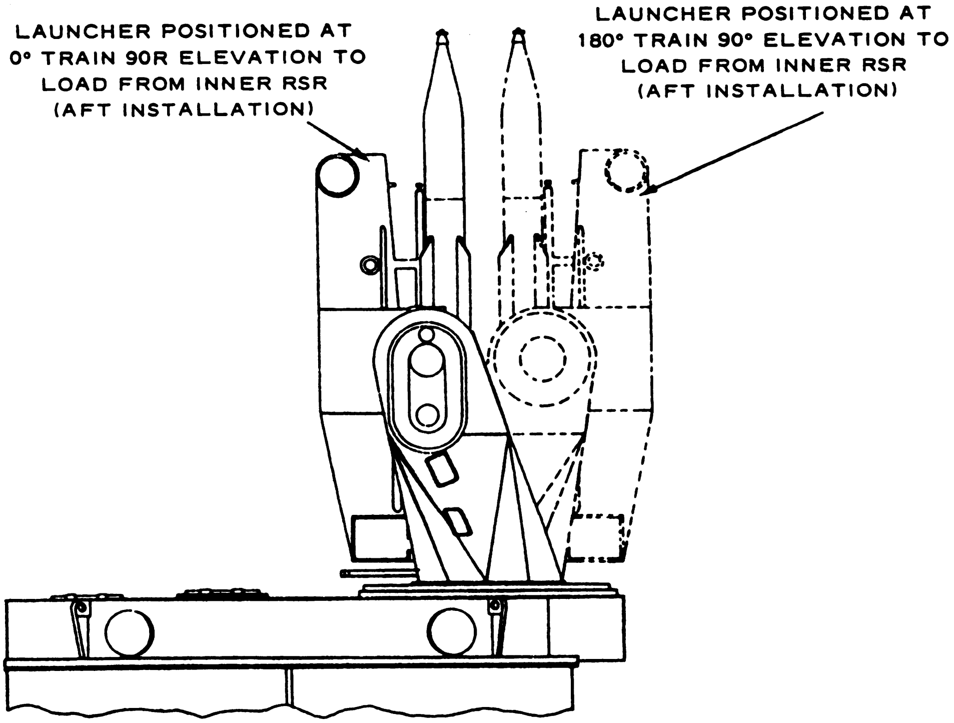

LAUNCHER POSITIONED AT 0° TRAIN 90R ELEVATION TO LOAD FROM INNER RSR (AFT INSTALLATION)
LAUNCHER POSITIONED AT 180° TRAIN 90° ELEVATION TO LOAD FROM INNER RSR (AFT INSTALLATION)

Figure 7-15.—Launcher load positions.

Contained in the guide arm assembly (fig. 7-16) is the missile arming device, contactor plug, dud jettison unit, and fin opener. The arming device and contactor plug perform the same functions as those on the Mk 10 system, except that missile firing is also accomplished through the contactor plug on the Mk 13. The dud jettison unit uses compressed nitrogen, stored in a flask in the guide arm, to power the ejector. The fin opener functions to erect the missile fins once missile firing is initiated.

The train and elevation power drives are located inside the center column of the magazine structure. The elevation system moves the guide arm through final drive components located in the right trunnion support.

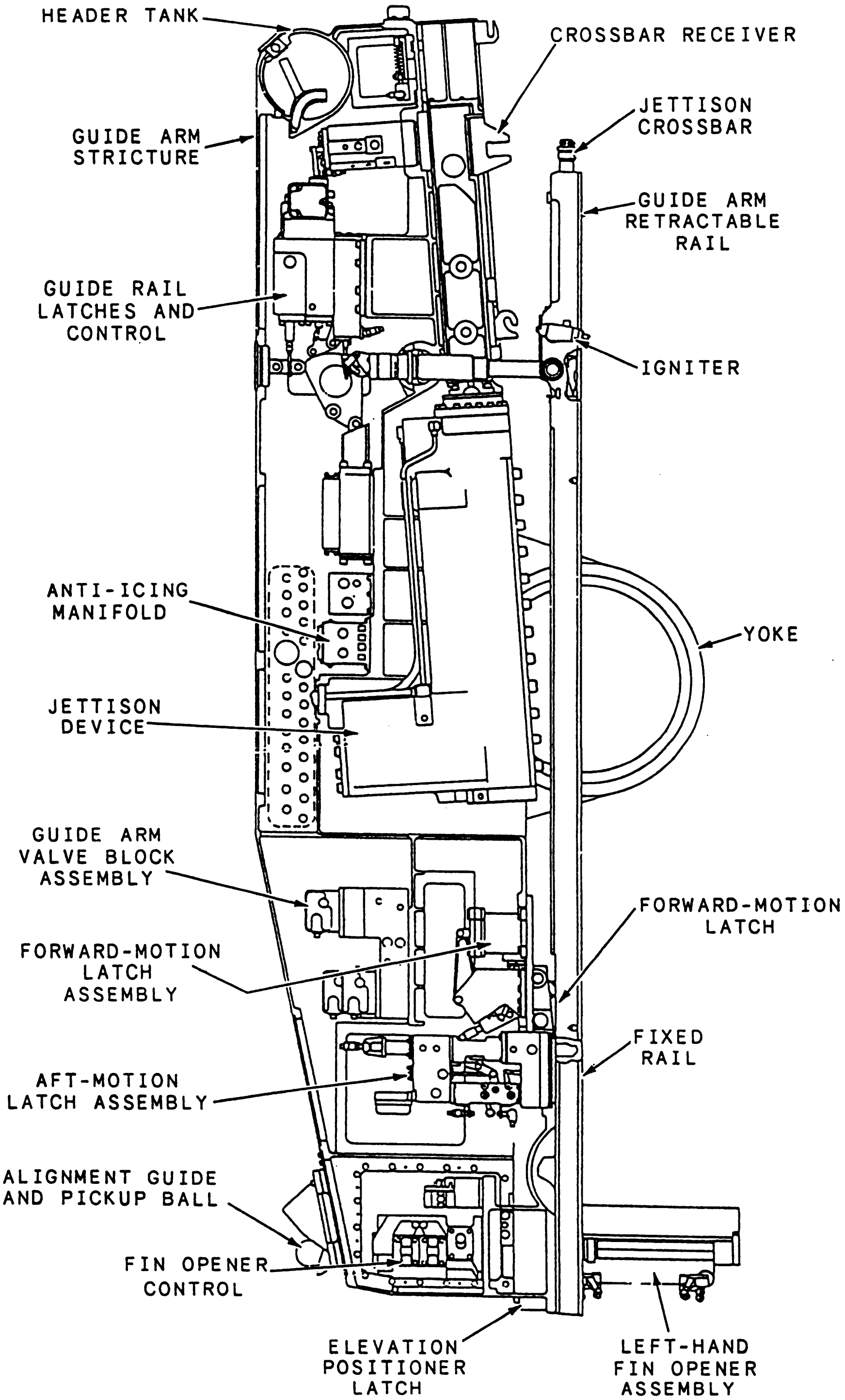

HEADER TANK
CROSSBAR RECEIVER
JETTISON CROSSBAR
GUIDE ARM STRICTURE
GUIDE ARM RETRACTABLE RAIL
GUIDE RAIL LATCHES AND CONTROL
IGNITER
ANTI-ICING MANIFOLD
YOKE
JETTISON DEVICE
GUIDE ARM VALVE BLOCK ASSEMBLY
FORWARD-MOTION LATCH
FORWARD-MOTION LATCH ASSEMBLY
FIXED RAIL
AFT-MOTION LATCH ASSEMBLY
ALIGNMENT GUIDE AND PICKUP BALL
FIN OPENER CONTROL
ELEVATION POSITIONER LATCH
LEFT-HAND FIN OPENER ASSEMBLY

Figure 7-16.—Guide arm assembly.

Launcher Control Units

As shown in figure 7-13, the Mk 13 GMLS has three main components: a power panel (EP-1), a control console (EP-2), and an electronics panel (EP-3).

The power panel (EP-1) is the power distribution unit for the GMLS. It contains transformers, circuit breakers, and motor contactors through which power is supplied to the systems drive motors and control circuits.

The control console (EP-2) (fig. 7-17) is the control unit for the GMLS. It contains the controls and indicators used to operate and monitor the operation of the system.

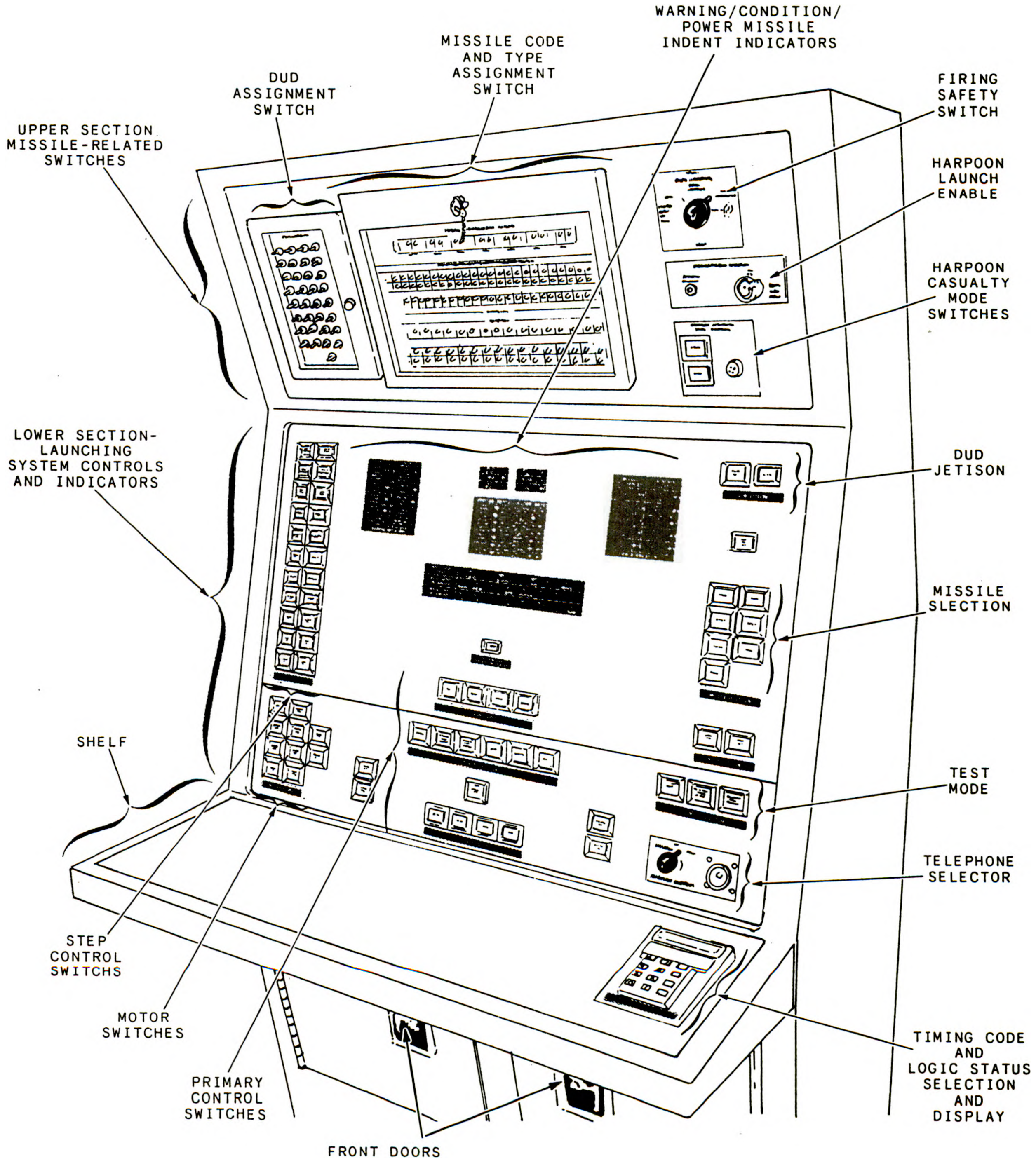

WARNING/CONDITION/ POWER MISSILE INDENT INDICATORS
MISSILE CODE AND TYPE ASSIGNMENT SWITCH
DUD ASSIGNMENT SWITCH
UPPER SECTION MISSILE-RELATED SWITCHES
FIRING SAFETY SWITCH
HARPOON LAUNCH ENABLE
HARPOON CASUALTY MODE SWITCHES
LOWER SECTION-LAUNCHING SYSTEM CONTROLS AND INDICATORS
DUD JETISON
MISSILE SLECTION
SHELF
TEST MODE
TELEPHONE SELECTOR
STEP CONTROL SWITCHS
MOTOR SWITCHES
PRIMARY CONTROL SWITCHES
TIMING CODE AND LOGIC STATUS SELECTION AND DISPLAY
FRONT DOORS

Figure 7-17.—The control console EP-2.

The electronics panel (EP-3) contains the electronic control and test equipment for launcher train and elevation power drives. The test module is used to test train and elevation nonpointing zones, nonfiring zones, and power failure of the power drives.

Mk 26 GMLS

The dual-arm Mk 26 GMLS (fig. 7-18) is designed to provide a quick response to a variety of targets. It is designed to fire both SM-1 and SM-2 (MR) and **ASROCs** (AntiSubmarine

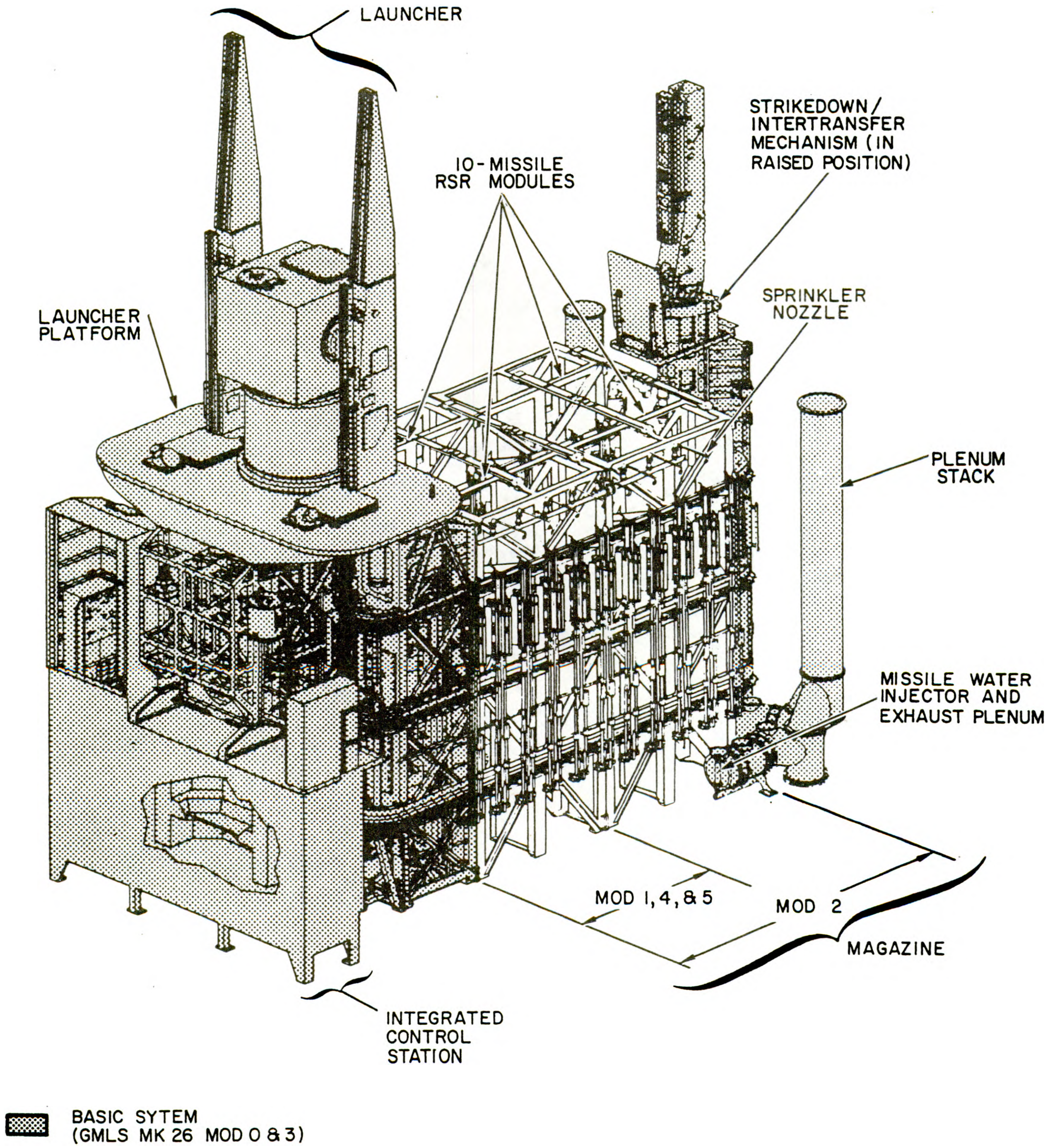

LAUNCHER
STRIKEDOWN/ INTERTRANSFER MECHANISM (IN RAISED POSITION)
10-MISSILE RSR MODULES
SPRINKLER NOZZLE
LAUNCHER PLATFORM
PLENUM STACK
MISSILE WATER INJECTOR AND EXHAUST PLENUM
MOD 1, 4, & 5
MOD 2
MAGAZINE
INTEGRATED CONTROL STATION
▨ BASIC SYTEM (GMLS MK 26 MOD 0 & 3)

Figure 7-18.—The Mk 26 GMLS with mod differences.

ROCkets), and is compatible with the same variety of associated control systems. The Mk 26 system is installed aboard the DD-993 *Kidd*, CGN-38 *Virginia*, and the first of the CG-47 Ticonderoga-class ships. The later CG-47 class ships are fitted with the Mk 41 VLS.

The Mk 26 GMLS consists of a launcher, magazine, and a launching system control. Depending on the mod configuration, the system may hold from 24 to 64 missiles. These missiles can be fired at a rate of approximately two missiles every 9 seconds.

Launcher

The launcher carriage (fig. 7-19) is supported by and attached to an 18′ by 10′ plate. This plate also serves as a mounting surface for the two dud jettison units, the blast doors, span rails, and some train drive components. The stand and base ring are configured similarly to the Mk 10 launcher. The base ring is supported by, and rotates inside of, the stand. The stand is also secured to the plate. Mounted to the top of the base ring is the trunnion support, which contains the elevation

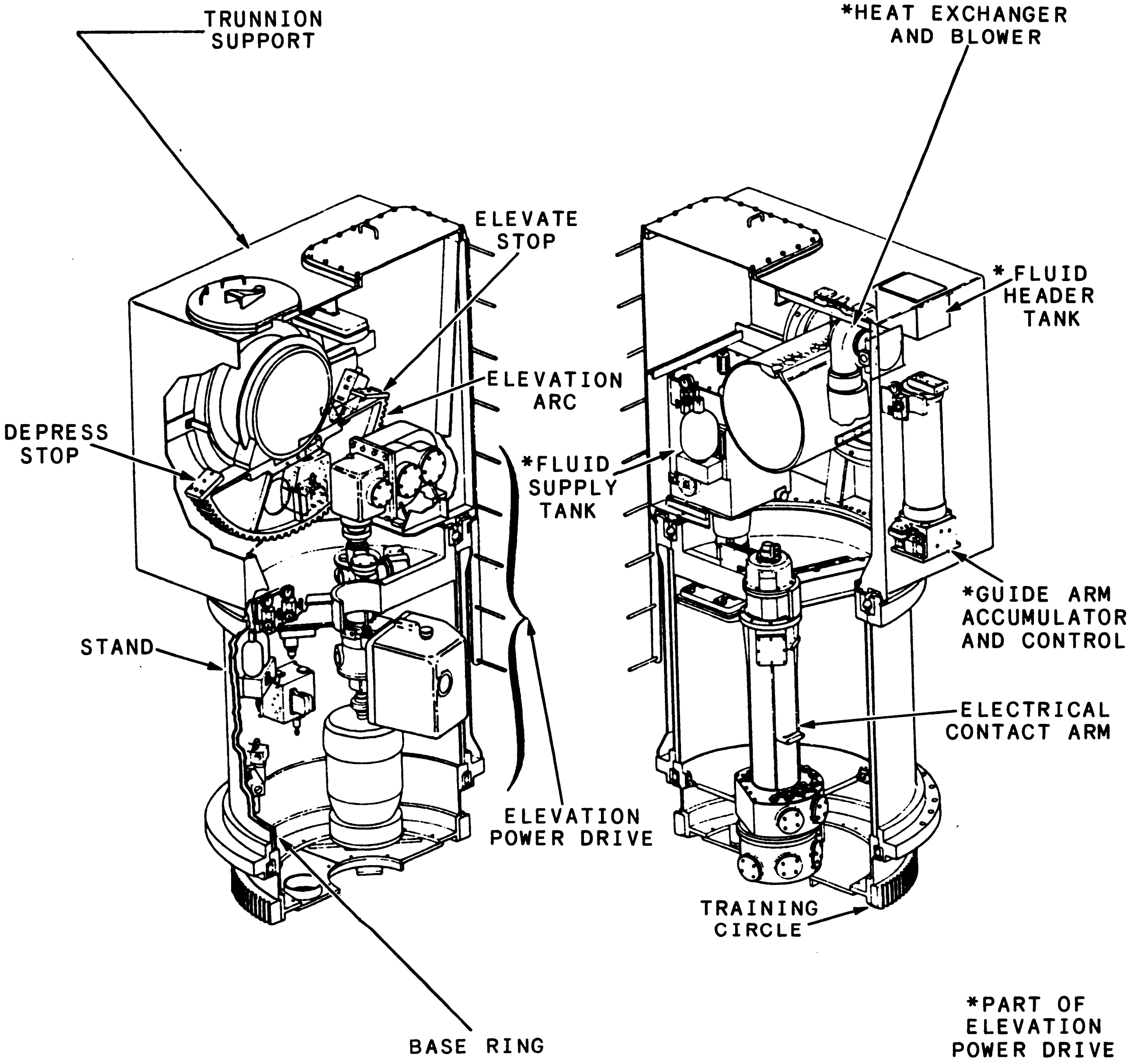


Figure 7-19.—Carriage, general arrangement.

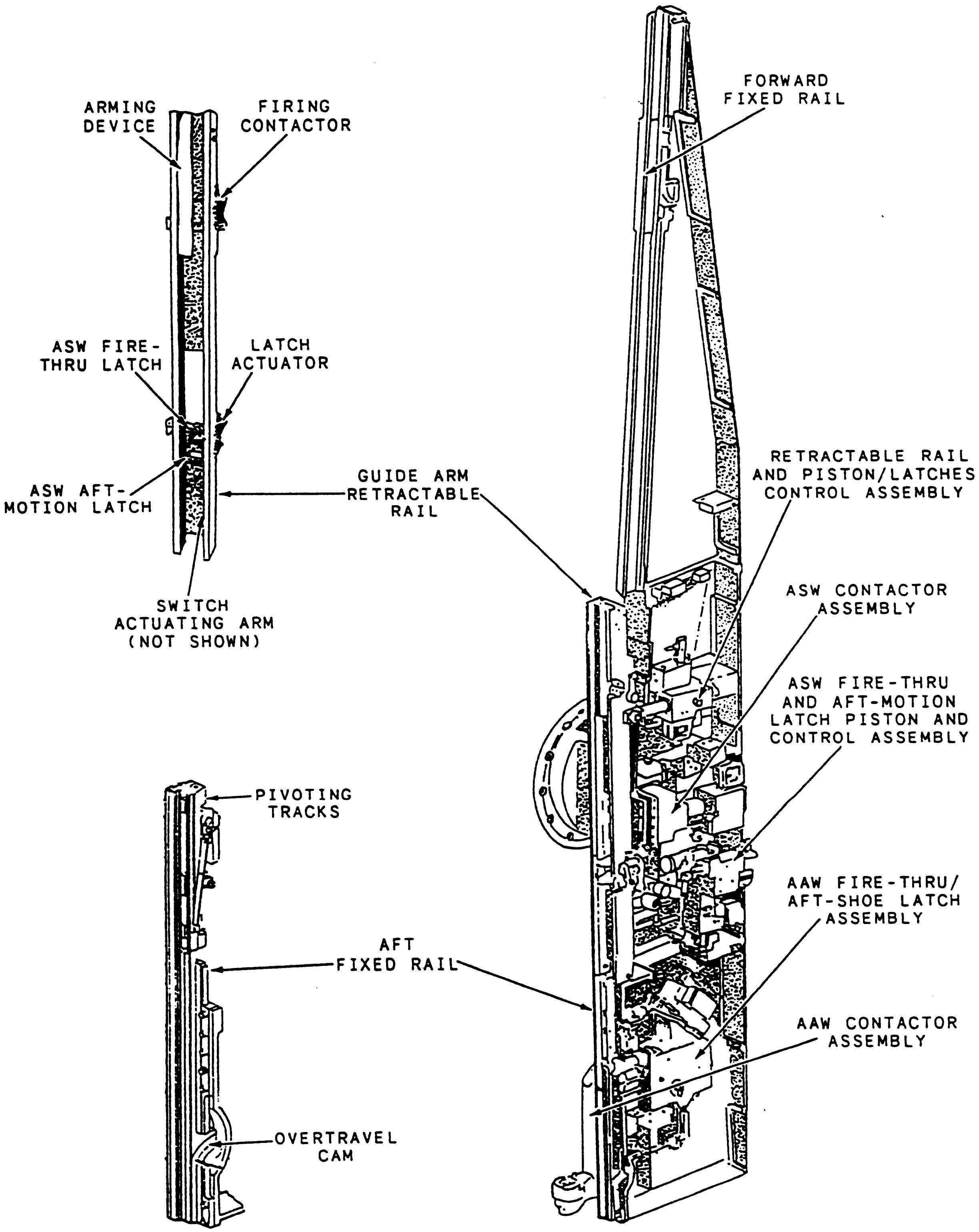

ARMING DEVICE
FIRING CONTACTOR
ASW FIRE-THRU LATCH
LATCH ACTUATOR
ASW AFT-MOTION LATCH
GUIDE ARM RETRACTABLE RAIL
SWITCH ACTUATING ARM (NOT SHOWN)
FORWARD FIXED RAIL
RETRACTABLE RAIL AND PISTON/LATCHES CONTROL ASSEMBLY
ASW CONTACTOR ASSEMBLY
ASW FIRE-THRU AND AFT-MOTION LATCH PISTON AND CONTROL ASSEMBLY
PIVOTING TRACKS
AAW FIRE-THRU/AFT-SHOE LATCH ASSEMBLY
AFT FIXED RAIL
AAW CONTACTOR ASSEMBLY
OVERTRAVEL CAM

Figure 7-20.—Guide arm components.

power drive and the bearings for trunnion/guide arm movement.

The guide arm (fig. 7-20) is a unique structure containing three different guide rails—one is movable and two are fixed. The aft fixed rail is about 50 inches long and contains a pair of hinged track segments, which open and close to form the rail track for a Standard missile's aft shoe.

The forward fixed rail is about 11-1/2 feet long and contains no functioning components. This rail is used only when firing an ASROC to provide the longer on-rail guidance required by these weapons.

The retractable rail is mounted between the two fixed rails and is about 6-1/2 feet long. During the loading operation, it extends to align with the aft fixed rail. This combination forms one continuous track for the missile or ASROC forward shoe. With a Standard missile, the rail remains extended until the weapon is launched. With an ASROC, the rail retracts to align with the forward fixed rail as soon as the weapon is loaded on to the guide arm. It remains retracted to form the longer guide rail until the weapon is launched.

Each guide arm also contains an arming mechanism and two extendable contactors, one for Standard missiles and one for ASROCs. These perform the same function as those earlier described on the Mk 10 and Mk 13 systems.

A blast door is mounted to the platform under each guide arm. When a load order is initiated, the blast door unlatches, raises, and swings aside to provide clearance for a missile with fins extended to pass through (the missile fins are extended in the magazine). When the blast door is open, a three-foot span rail extends to bridge the distance between the launcher aft rail and the magazine fixed loader rail. The span rail is not part of the blast door, but is a separate unit. Once the missile is loaded on the launcher, the span rail retracts and the blast door closes to form a weather and blast tight seal.

The dud jettison unit for the Mk 26 GMLS is a unique device. It uses an explosive gas generator to provide the ejecting force. Both the missile and an expendable piston are jettisoned over the side. The ejectors are located on the weather deck in a position similar to the ejectors on the Mk 10 GMLS.

Magazine

The magazine contains all the components necessary to stow, load, unload, strikedown, and intertransfer guided missiles and ASROCs. The major component located in the magazine is the ready service ring (RSR). All magazine components either attach to, or are a part of, the RSR. This includes the hoist, hanger rail assemblies, and strikedown mechanism.

Missiles are stored vertically; one in each hanger rail assembly. The hanger rail assemblies (fig. 7-21) are linked together by three chain sections forming a continuous link around the

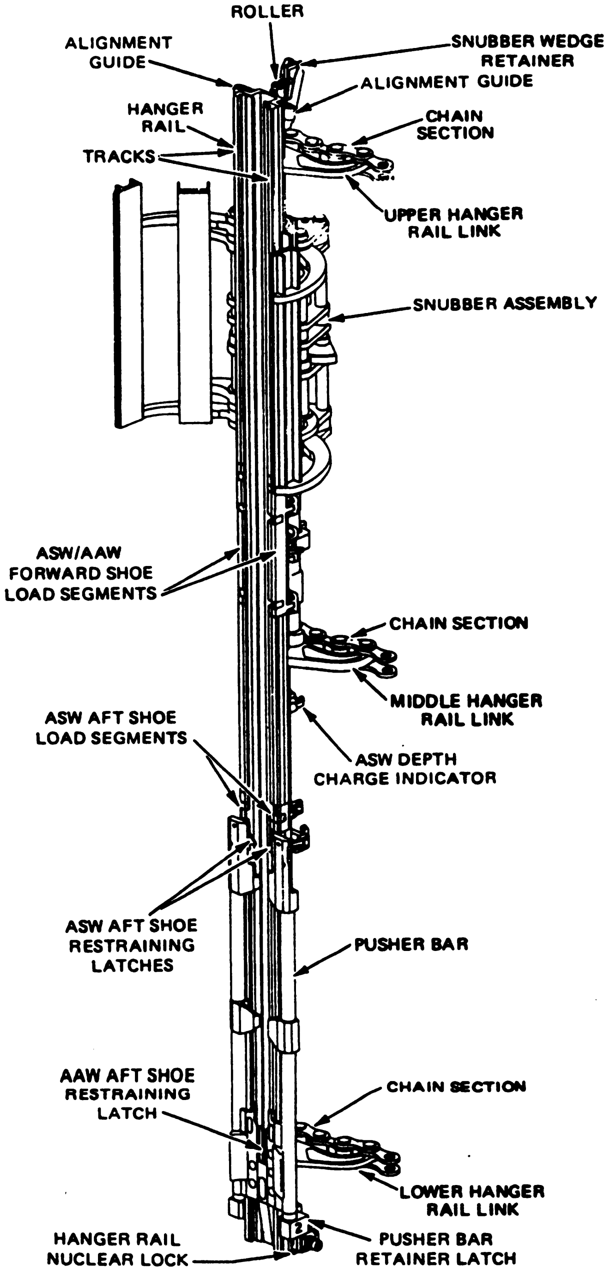


Figure 7-21.—Hanger rail assembly.

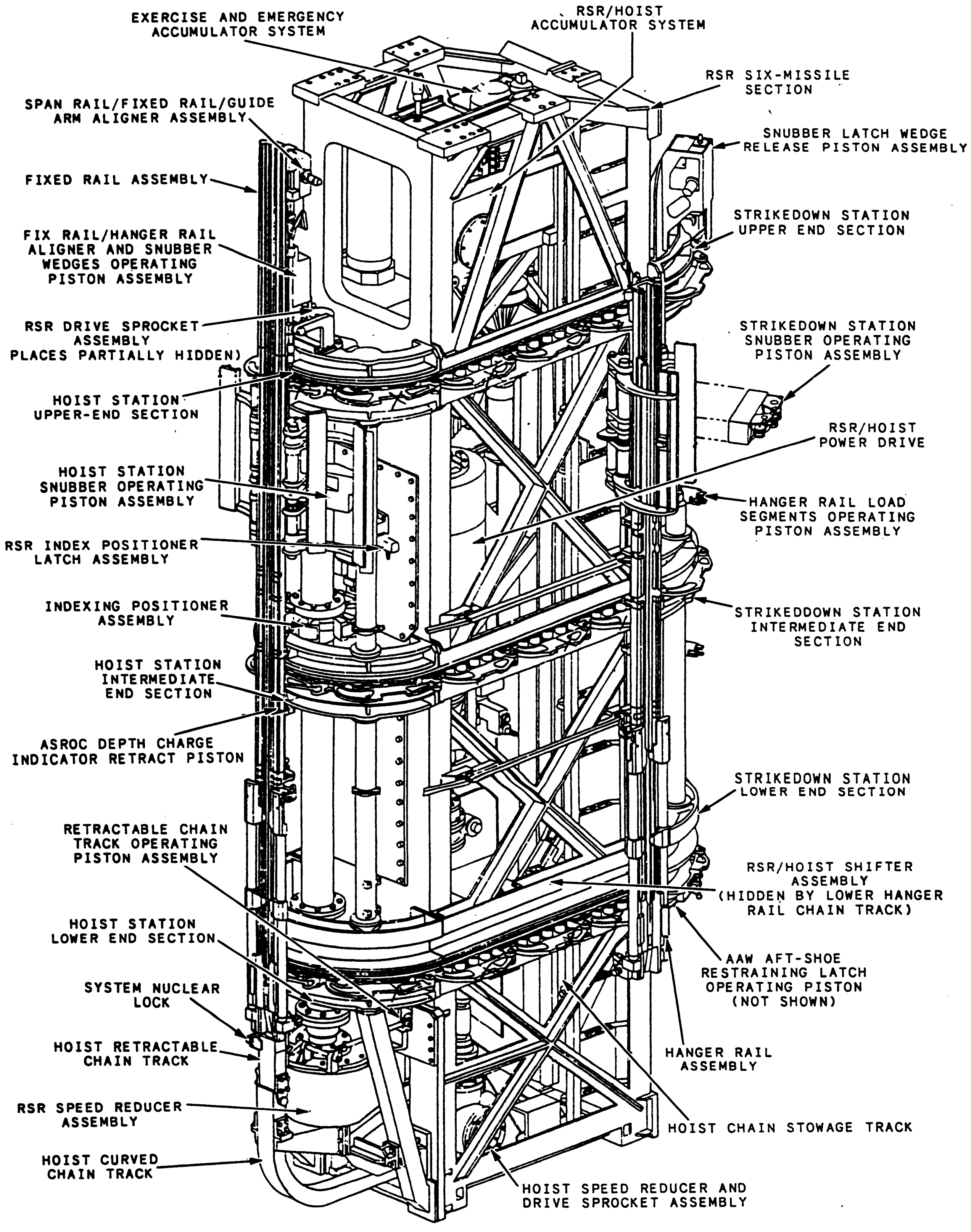

EXERCISE AND EMERGENCY ACCUMULATOR SYSTEM
RSR/HOIST ACCUMULATOR SYSTEM
RSR SIX-MISSILE SECTION
SPAN RAIL/FIXED RAIL/GUIDE ARM ALIGNER ASSEMBLY
SNUBBER LATCH WEDGE RELEASE PISTON ASSEMBLY
FIXED RAIL ASSEMBLY
STRIKEDOWN STATION UPPER END SECTION
FIX RAIL/HANGER RAIL ALIGNER AND SNUBBER WEDGES OPERATING PISTON ASSEMBLY
RSR DRIVE SPROCKET ASSEMBLY (3 PLACES PARTIALLY HIDDEN)
STRIKEDOWN STATION SNUBBER OPERATING PISTON ASSEMBLY
HOIST STATION UPPER-END SECTION
RSR/HOIST POWER DRIVE
HOIST STATION SNUBBER OPERATING PISTON ASSEMBLY
HANGER RAIL LOAD SEGMENTS OPERATING PISTON ASSEMBLY
RSR INDEX POSITIONER LATCH ASSEMBLY
INDEXING POSITIONER ASSEMBLY
STRIKEDDOWN STATION INTERMEDIATE END SECTION
HOIST STATION INTERMEDIATE END SECTION
ASROC DEPTH CHARGE INDICATOR RETRACT PISTON
STRIKEDOWN STATION LOWER END SECTION
RETRACTABLE CHAIN TRACK OPERATING PISTON ASSEMBLY
RSR/HOIST SHIFTER ASSEMBLY (HIDDEN BY LOWER HANGER RAIL CHAIN TRACK)
HOIST STATION LOWER END SECTION
AAW AFT-SHOE RESTRAINING LATCH OPERATING PISTON (NOT SHOWN)
SYSTEM NUCLEAR LOCK
HOIST RETRACTABLE CHAIN TRACK
HANGER RAIL ASSEMBLY
RSR SPEED REDUCER ASSEMBLY
HOIST CHAIN STOWAGE TRACK
HOIST CURVED CHAIN TRACK
HOIST SPEED REDUCER AND DRIVE SPROCKET ASSEMBLY

Figure 7-22.—RSR general arrangement.

RSR. The missile is physically held in the hanger rail by a snubber assembly, which grips around the top of the missile, and a pusher bar, which holds the aft shoe.

When a load order is initiated, the hanger rail containing the desired missile is indexed to the hoist position (fig. 7-22) and locked to the RSR fixed rail. The snubbers are then opened and the hoist is raised. As the hoist raises, the hoist pawl engages the pusher bar, moving it and the missile to the launcher. The launcher disengages the missile from the pusher bar and the hoist returns it to the magazine.

Launching System Control

The launching system control components (fig. 7-23) perform three main functions: (1) distribute electrical power; (2) process system orders and responses; and (3) perform tests to determine system readiness.

These components are arranged in close proximity to each other and referred to as the **Integrated Control Station** (ICS). The ICS is made up of a power distribution center (PDC), the main control console (MCC), right- and left-hand circuit card housings, and the train and elevation test center. These units are referred to by their full name or abbreviation, not by the old system of EP-panel numbers. The function of these units is similar to those described earlier on other systems.

Mk 41 VLS

The Mk 41 Vertical Launch System is a drastic departure from the systems we have described up to now. Unlike previously described systems, the Mk 41 launcher performs all the functions of both a magazine and a launcher. The system (fig. 7-24) consists of one or two launchers and two launcher control units (LCUs), and is capable of interfacing with any one of three **weapon control systems** (WCS) to fire a variety of missiles (fig. 7-25).

Launcher

The launcher consists of a block of 5- and 8-cell modules. Each module is equipped with its own **Launcher Sequencer** (LSEQ). The cells hold one missile canister each. The five-cell module contains the **strikedown assembly**, which occupies the area of three missile cells. The canisters are

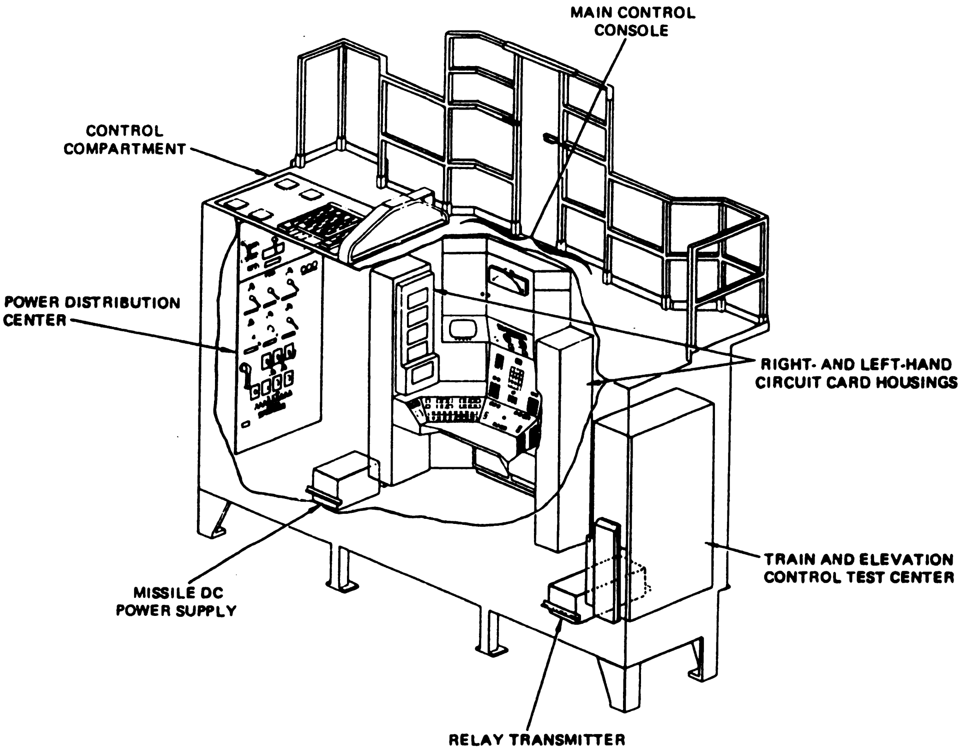

MAIN CONTROL CONSOLE
CONTROL COMPARTMENT
POWER DISTRIBUTION CENTER
RIGHT- AND LEFT-HAND CIRCUIT CARD HOUSINGS
TRAIN AND ELEVATION CONTROL TEST CENTER
MISSILE DC POWER SUPPLY
RELAY TRANSMITTER

Figure 7-23.—Launching system control components.

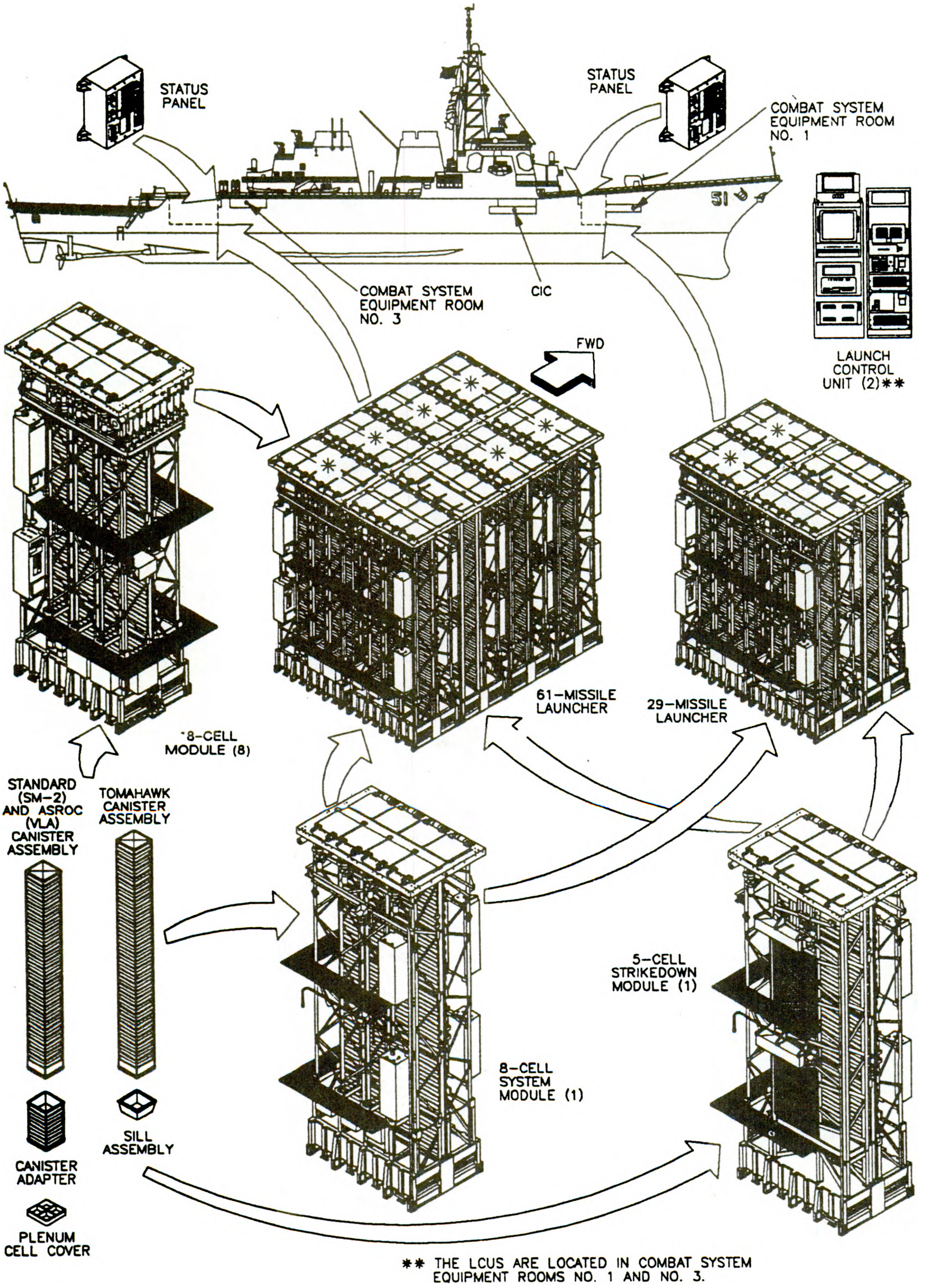

STATUS PANEL
STATUS PANEL
COMBAT SYSTEM EQUIPMENT ROOM NO. 1
51
COMBAT SYSTEM EQUIPMENT ROOM NO. 3
CIC
FWD
LAUNCH CONTROL UNIT (2)**
8-CELL MODULE (8)
61-MISSILE LAUNCHER
29-MISSILE LAUNCHER
STANDARD (SM-2) AND ASROC (VLA) CANISTER ASSEMBLY
TOMAHAWK CANISTER ASSEMBLY
5-CELL STRIKEDOWN MODULE (1)
8-CELL SYSTEM MODULE (1)
CANISTER ADAPTER
SILL ASSEMBLY
PLENUM CELL COVER
** THE LCUS ARE LOCATED IN COMBAT SYSTEM EQUIPMENT ROOMS NO. 1 AND NO. 3.

Figure 7-24.—The Vertical Launch System (VLS).

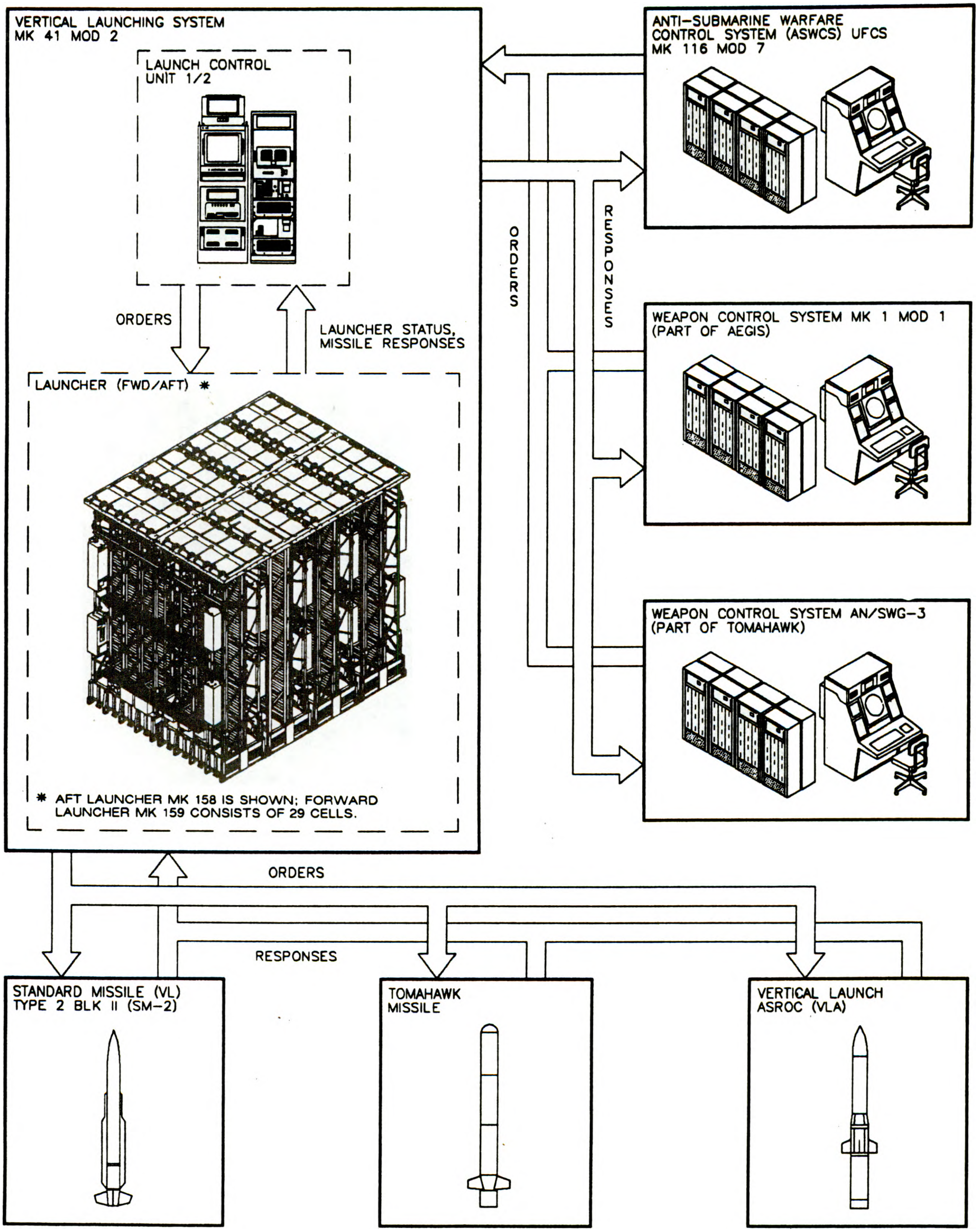

VERTICAL LAUNCHING SYSTEM
MK 41 MOD 2
LAUNCH CONTROL UNIT 1/2
ORDERS
LAUNCHER STATUS, MISSILE RESPONSES
LAUNCHER (FWD/AFT) *
* AFT LAUNCHER MK 158 IS SHOWN; FORWARD LAUNCHER MK 159 CONSISTS OF 29 CELLS.
ANTI-SUBMARINE WARFARE CONTROL SYSTEM (ASWCS) UFCS
MK 116 MOD 7
ORDERS
RESPONSES
WEAPON CONTROL SYSTEM MK 1 MOD 1
(PART OF AEGIS)
WEAPON CONTROL SYSTEM AN/SWG-3
(PART OF TOMAHAWK)
ORDERS
RESPONSES
STANDARD MISSILE (VL)
TYPE 2 BLK II (SM-2)
TOMAHAWK MISSILE
VERTICAL LAUNCH ASROC (VLA)

Figure 7-25.—System equipment and combat system integration.

individually protected from high temperature and internal fire by a deluge system, while the entire module is protected by a sprinkler system.

LAUNCH SEQUENCER (LSEQ).—The LSEQ is an interface unit between the controlling LCU and the module equipment. It functions to:

- — monitor module and cell status
- — transfer data between the LCU and the missiles
- — initiate the deluge function as necessary
- — command the opening and closing of uptake and cell hatches

CANISTERS.—Each canister is a watertight shipping container for a single missile. The system is currently able to launch SM-2 (MR), **Vertical Launch ASROC** (VLA), and both surface and land attack Tomahawk. There are four different types of canisters— one each for SM-2 and VLA, and two for Tomahawk. The SM-2 and VLA missile canisters are shorter than the Tomahawk canisters and, therefore, require a canister adapter for loading into the cell.

The missile canister, once installed in the launcher cell, is connected to the system with the umbilical connector, the deluge connector, and the coding plug. Through these connections canister temperature is monitored, deluge water is supplied, and prelaunch information is supplied to the missile.

Each canister is equipped with a manual safe/enable switch. The switch is manually set to SAFE to prevent the missile from being accidentally activated. This is done during all handling, transportation, and storage operations, and during war-game exercises.

STRIKEDOWN ASSEMBLY.—The strikedown assembly (fig. 7-26) includes a crane mounted on an elevator. The crane is used for maintenance, handling SM-2 and VLA canisters, and for removing any empty canister. Servicing loaded Tomahawk canisters requires the use of a pierside crane. When the crane is not in use, it is folded into the stow position and lowered into the module by the elevator.

DELUGE SYSTEM.—The deluge system sprays cooling water within the affected canister if a restrained firing (the missile remains in the canister) or canister overtemperature condition occurs. The deluge system water supply is a fresh water accumulator tank, which is pressurized with high pressure air. When the system is activated, pressure in the accumulator tank begins to drop. When it drops below firemain pressure, a valve opens allowing seawater from the ship's firemain to enter the system, and the deluge function is completed using seawater.

SPRINKLER SYSTEM.—Each module is protected by an automatic dry-type sprinkler system. This type system was described in an earlier chapter. Note the location of the HSDs and sprinkler heads in figure 7-26.

Launcher Control Unit

Under direction from the WCS, the LCU controls the LSEQ in each module during VLS operations. During normal operations on a ship with two launchers, each LCU controls one launcher. At the same time, however, each LCU is constantly updating and storing data on the status of both launchers. This is to enable either LCU to take control of both launchers in case one is disabled.

Each LCU contains a **Data Processing Set** (DPS). The DPS controls the sequence of functions in the VLS and transfers data between the controlling WCS and each LSEQ. Each DPS performs the following functions:

- — Launch control
- — Interface management
- — Equipment management
- — Fault detection
- — System support

The LCU also contains a **Signal Data Recorder/Reproducer** (CMTU) and an **Input/Output Control Console** (IOCC). The CMTU is a data cartridge magnetic tape unit that records data from, and transfers data to, the DPS. The IOCC provides for manual input to the DPS through a keyboard or punch tape. The IOCC also drives a printer and punch tape perforator to provide hard-copy output of system data and error messages for tactical evaluation.

The normal launch sequence begins when the WCS selects a missile for launch. The WCS may

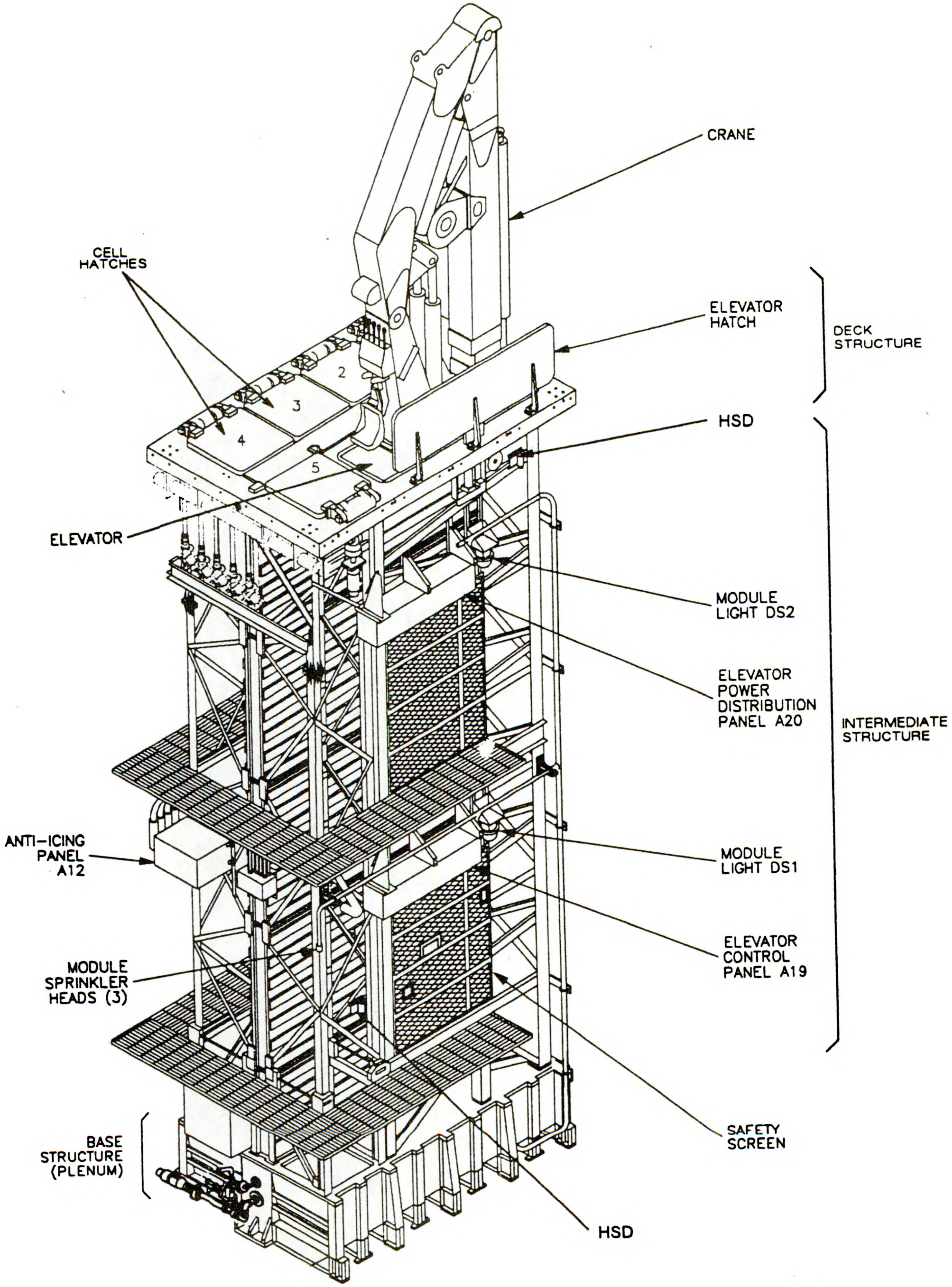


Figure 7-26.—Five-cell strikedown module.

select a particular missile or missile type. If a particular missile is selected, the LCS checks the status of that missile for firing. If a missile type is selected, the LCU assigns a missile for firing. The system then prepares the missile and launcher for firing. This includes opening the vent and cell hatches, closing the plenum drain, and programing the missile. Next, the system supplies firing voltage to ignite the missile's DTRM, then checks to ensure the missile has been successfully launched.

HARPOON WEAPON SYSTEM (HWS)

The Harpoon missile can be launched from surface, subsurface, and airborne platforms. However, in this section we will discuss only the surface-launched version of the Harpoon Weapon System (HWS). The surface HWS may employ any one of three launchers presently in use. The missile may be fired from the Mk 13 Mod 4 GMLS, the Mk 16 ASROC launcher, or from the Harpoon canister launcher system.

This section on the HWS will be presented differently than previous sections. Up to now, we have discussed only individual systems as they function in the detection, control, delivery, or destruction role. This is not possible with the HWS, since the components that perform these functions are not easily distinguishable from each other.

System Components

The core of the system is the **Harpoon Ship Command-Launch Control Set** (HSCLCS), which consists of the **Harpoon Control Console** (HCC) and the **Weapon Control Indicator Panel** (WCIP). Since the Mk 13 Mod 4 GMLS has already been described, we will only cover the canister launcher here. The Mk 16 ASROC launcher will not be covered in this text.

The most current version of the HWS is the AN/SWG-1A used with the RGM-84D missile. This version allows for the greatest variation of engagement options. These options center around the various flight and attack profiles that the newer missile is capable of being programed to perform. These options will be discussed later.

HARPOON CONTROL CONSOLE (HCC).—The HCC receives remote target data, computes a fire control solution, monitors the HWS, and produces missile and launcher orders. It also supplies the system with DC operating power. As shown in figure 7-27 (a foldout at the end of this chapter), the system receives target information from all of the ship's sensors. The system may also receive target information, through the data link, from other ship's sensors. The operator may also input additional target information through the WCIP.

WEAPON CONTROL INDICATOR PANEL (WCIP).—The WCIP is the principle operating station for the HWS. The WCIP contains the **Graphic Display System** (GDS), through which the operator inputs engagement planning. Engagement planning includes the selection of launch mode and missile flight path.

Canister Missile Launcher (CML)

The CML is used to provide the missile/canister with a secure launch platform. A ship will normally be fitted with two launchers, each capable of supporting four missile/canisters. The CML maintains the Harpoon missile/canister at a fixed 35-degree elevation angle. The CML also includes the interface equipment between the missile/canister and the HSCLCS.

Canister

The canister is a cylindrical shell structure containing launch rails, ignition connectors, control connectors, and stacking frames. The canister provides all weather protection for the missile and electrical connections for interface with the HSCLCS through the launcher.

RGM-84D

The Harpoon missile is an active homing missile. Prior to launch, it is programed to fly a certain course, then begin searching for a target. Once fired, the missile receives no further updates from the system. It is totally self-sustained as it seeks a target.

At this writing, the Navy has all four of the Harpoon missile variations, RGM-84A-D, in inventory. Each updated version includes new flight path and attack options, as well as updated ECM defeating capabilities. The Harpoon flight path illustrated in chapter 6 was that of the RGM-84A. Some of the performance options available on the RGM-84D (fig. 7-28) include:

— High Altitude Flyout

— Presearch Skim Altitude

— Waypoints

— Terminal Attack Mode

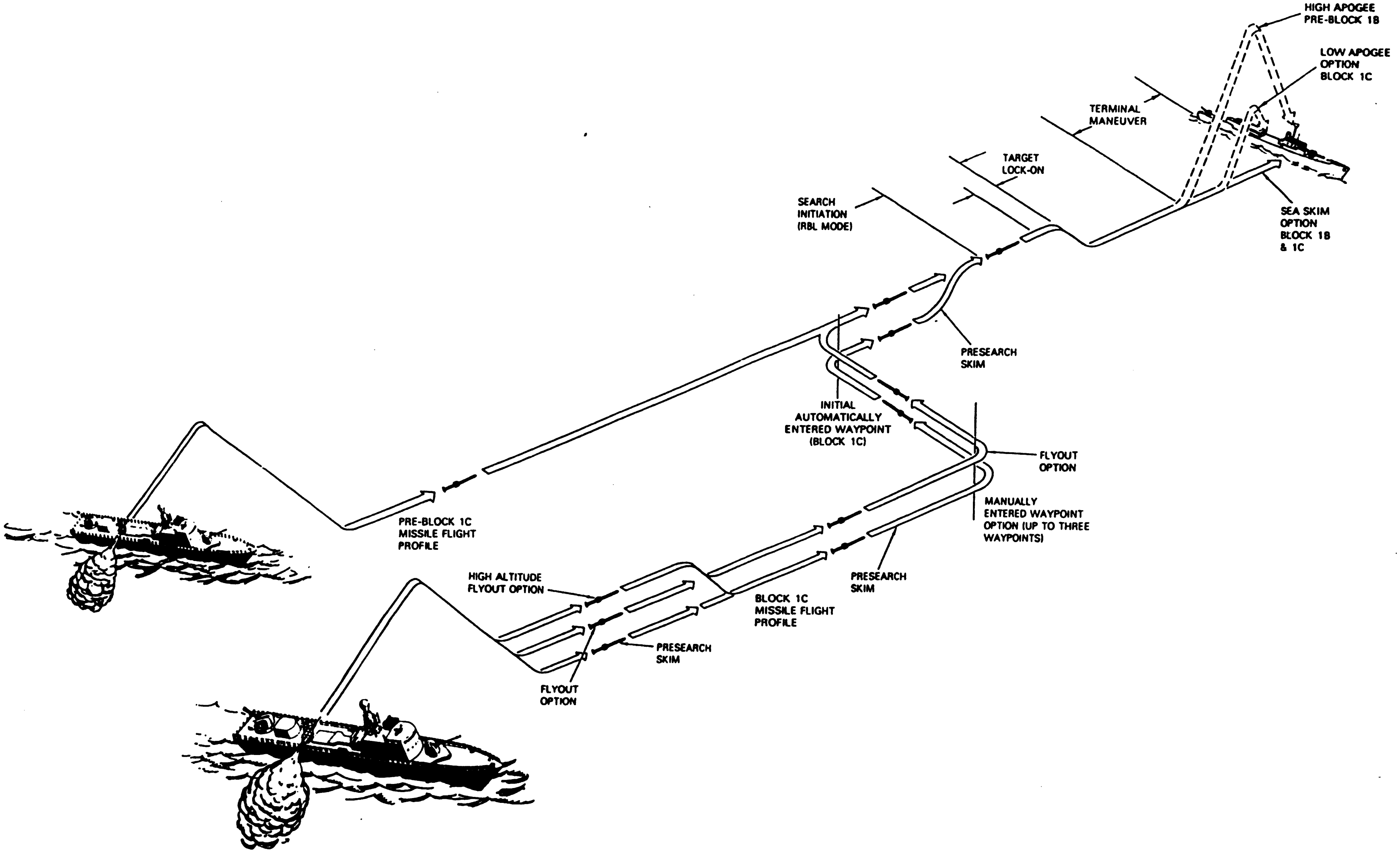

HIGH APOGEE PRE-BLOCK 1B
LOW APOGEE OPTION BLOCK 1C
TERMINAL MANEUVER
TARGET LOCK-ON
SEARCH INITIATION (RBL MODE)
SEA SKIM OPTION BLOCK 1B & 1C
PRESEARCH SKIM
INITIAL AUTOMATICALLY ENTERED WAYPOINT (BLOCK 1C)
FLYOUT OPTION
MANUALLY ENTERED WAYPOINT OPTION (UP TO THREE WAYPOINTS)
PRE-BLOCK 1C MISSILE FLIGHT PROFILE
HIGH ALTITUDE FLYOUT OPTION
PRESEARCH SKIM
BLOCK 1C MISSILE FLIGHT PROFILE
PRESEARCH SKIM
FLYOUT OPTION

Figure 7-28.—RGM-84D flight and attack options.

HIGH ALTITUDE FLYOUT.—The missile will cruise at a preset high altitude until it reaches a predetermined range.

PRESEARCH SKIM ALTITUDE.—The missile will cruise at sea skim altitude until the search mode is started.

WAYPOINTS.—Up to three waypoints or turns may be incorporated into the missile's flight path to the target. Waypoints are used to disguise the location of the firing ship, and to fire around friendly vessels or a land mass.

TERMINAL ATTACK MODE.—The missile will attack at a sea skim altitude or a low apogee pop-up.

Depending upon the tactical situation, the operator may select one or several of these options.

TOMAHAWK WEAPON SYSTEM (TWS)

As with the HWS, the elements of TWS are not easily distinguished from each other. The system includes all the equipment necessary to plan the engagement, control the launcher, launch the missile, and to find and destroy the target. Therefore, this section will contain a brief overview of the complete system. Figure 7-29 (a foldout at the end of this chapter) illustrates the Mk 37 TWS, which is configured for use aboard ships equipped with the Mk 41 VLS. Ships equipped with an **Armored Box Launching System** (ABLS) use the Mk 36 TWS.

The Tomahawk Weapon System is an all weather, over-the-horizon, offensive combat system capable of engaging surface ships and preselected land targets at long ranges. The Mk 37 system consists of:

1. Weapon Control System (WCS) AN/SWG-3 (the Mk 36 uses the AN/SWG-2)
2. Tomahawk missile
3. Mk 41 VLS (the Mk 36 uses the ABLS)

Weapon Control System (WCS)

The Weapon Control System (WCS) is the controlling element of the Tomahawk Weapon System (TWS). The WCS receives track and target data from weapon and sensor systems of own and other ships. From the track data, targets are selected by the WCS operators for engagement. The WCS is divided into two functional groups:

1. Track Control Group (TCG)
2. Launcher Control Group (LCG)

The TCG and LCG are each composed of operator consoles and unattended equipment. Operating personnel are positioned at four **Operator Interactive Display Terminals** (OIDTs). The OIDTs contain the systems controls, indicators, and displays.

TRACK CONTROL GROUP (TCG).—The TCG contains two OIDTs and five groups of unattended equipment (called **Control Centers** [CCs]). The TCG functions to process target and track data, perform target and threat evaluation, and allow operators to perform engagement planning and weapons assignment.

The TCG uses data supplied by interfacing units such as:

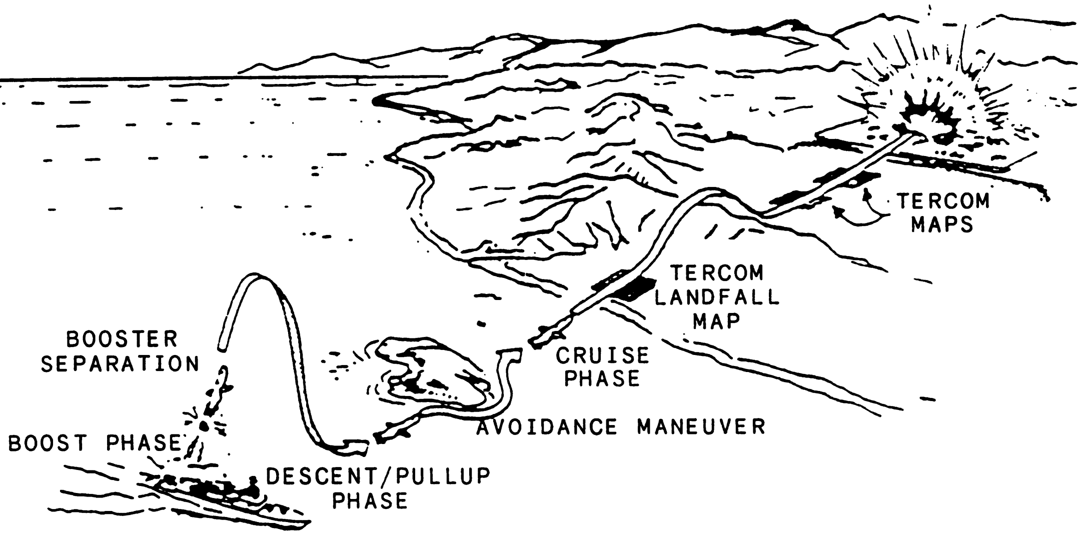
1. NTDS/CDS (described in chapter 8)
2. Satellite Communication (SATCOM)
3. Ownship's sensors (described in chapter 8).

LAUNCHER CONTROL GROUP (LCG).—The LCG consists of two OIDTs and three CCs. The LCG receives engagement data and launch orders from the TCG and establishes a computerized data base from which ordered engagements are scheduled and monitored through launch. The schedule consists of the selected missile(s) being prepared for launch by the inputting of target parameters, activation of the launching system, and firing of the missile.

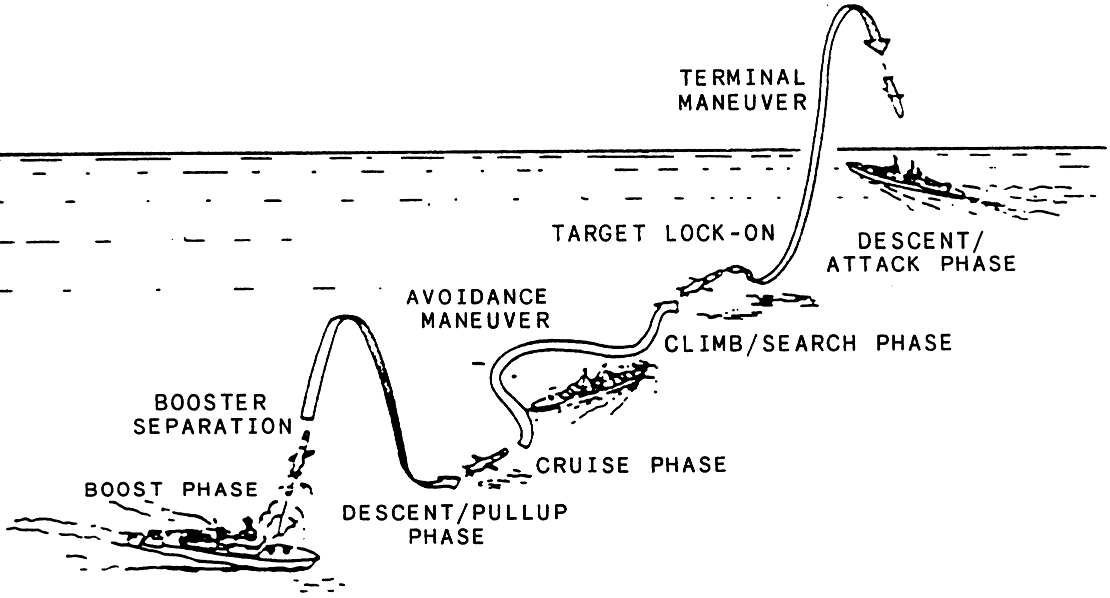
CONTROL CENTERS (CCs).—The CCs, as shown in figure 7-29, perform many complex functions that are beyond the scope of this manual. Each unit illustrated, however, is named and supplied with a brief description of its primary function in the system.

TOMAHAWK MISSILE

The Tomahawk missile, RGM-109A/B/C/D, is a Sea-Launched Cruise Missile (SLCM); that is, a pilotless, winged, and powered aircraft launched from surface ships. Like the Harpoon missile, the Tomahawk flies a low altitude, multilegged flightpath to avoid detection and gain survivability. The missile is designed to reach and destroy over-the-horizon targets with pin-point accuracy. Figure 7-30 illustrates the typical land and sea attack profiles of the Tomahawk missile.



LAND ATTACK TOMAHAWK MISSILE FLIGHT



ANTISHIP TOMAHAWK MISSILE FLIGHT

Figure 7-30.—Typical land attack and antiship flight profiles of the Tomahawk missile.

ARMORED BOX LAUNCHING SYSTEM (ABLS)

The Armored Box Launching System (ABLS) (fig. 7-31) consists of an **Armored Box Launcher** (ABL) and a hydraulic power unit. The ABL is a stationary mounted box with an elevating cover assembly. The cover assembly contains four missile canisters and is stowed at zero degrees then hydraulically raised to 35 degrees for missile firing.

The launcher can be operated for testing, troubleshooting, and maintenance from the local control panel located between the forward doors of the ABL. The ABL is also equipped with a Halon fire suppression system and a salt water deluge system.

SUMMARY

In this chapter we described, in general terms, the major missile launchers and launching systems in the fleet today. With the advance of technology, the definitions and descriptions used in the past may soon be obsolete. The older compartmentalized view of the ship's weapon system is rapidly giving way to the more modern and efficient "one system" concept. This change will become more evident in the next chapter as we describe detection systems.

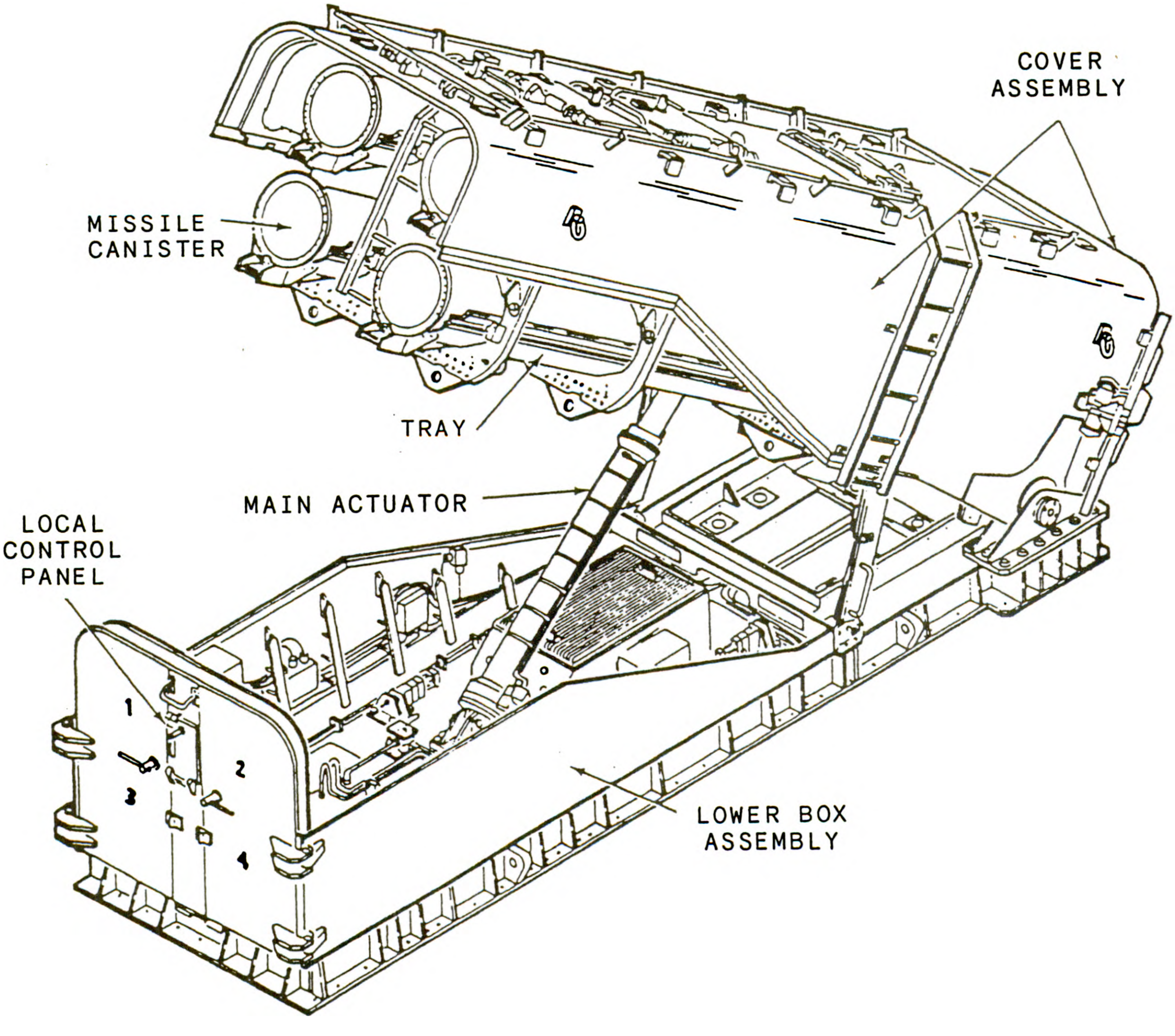


Figure 7-31.—The Armored Box Launcher (ABL).

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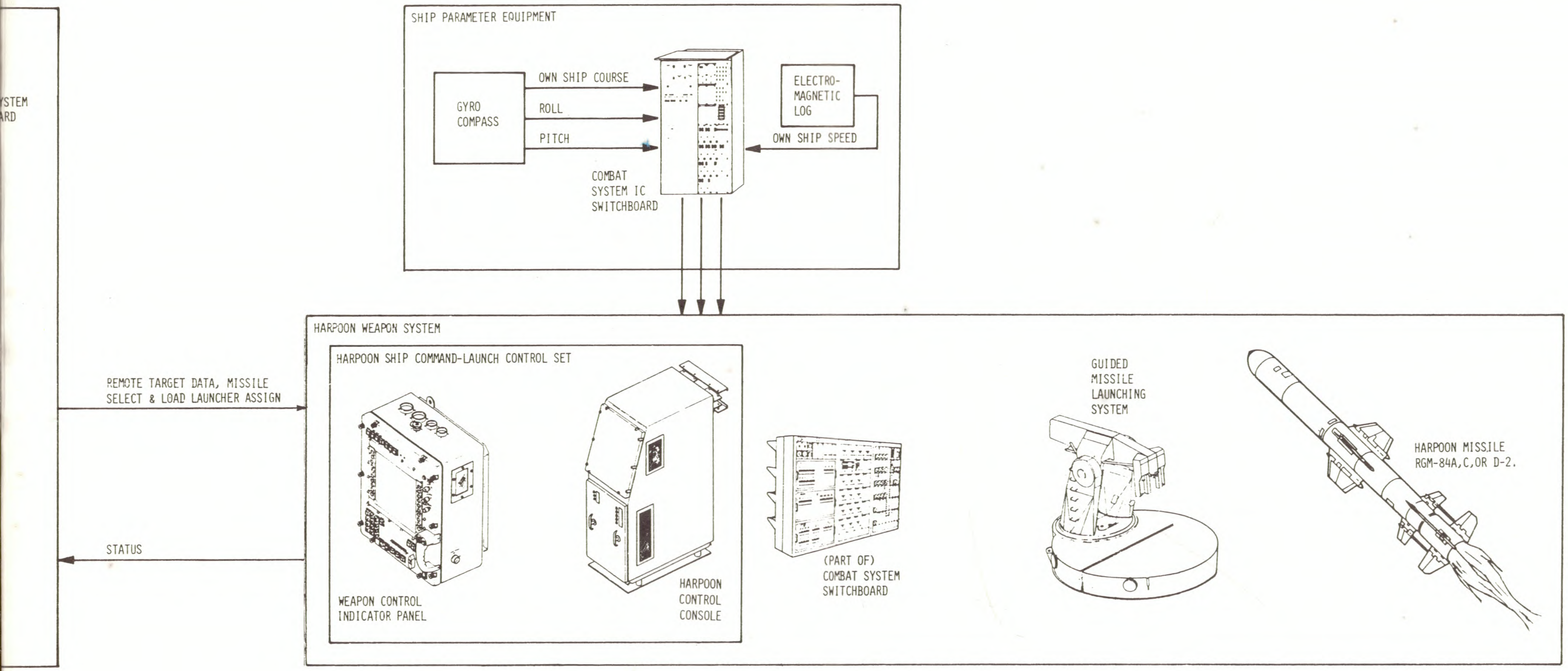
Vertical Launching System Mark 41 Mod 0/1, SW394-AF-MMO-020, Naval Sea Systems Command, Washington, D.C., 1987.


YSTEM
ARD
SHIP PARAMETER EQUIPMENT
GYRO COMPASS
OWN SHIP COURSE
ROLL
PITCH
ELECTRO-MAGNETIC LOG
OWN SHIP SPEED
COMBAT SYSTEM IC SWITCHBOARD
HARPOON WEAPON SYSTEM
HARPOON SHIP COMMAND-LAUNCH CONTROL SET
REMOTE TARGET DATA, MISSILE SELECT & LOAD LAUNCHER ASSIGN
STATUS
WEAPON CONTROL INDICATOR PANEL
HARPOON CONTROL CONSOLE
(PART OF) COMBAT SYSTEM SWITCHBOARD
GUIDED MISSILE LAUNCHING SYSTEM
HARPOON MISSILE RGM-84A,C,OR D-2.

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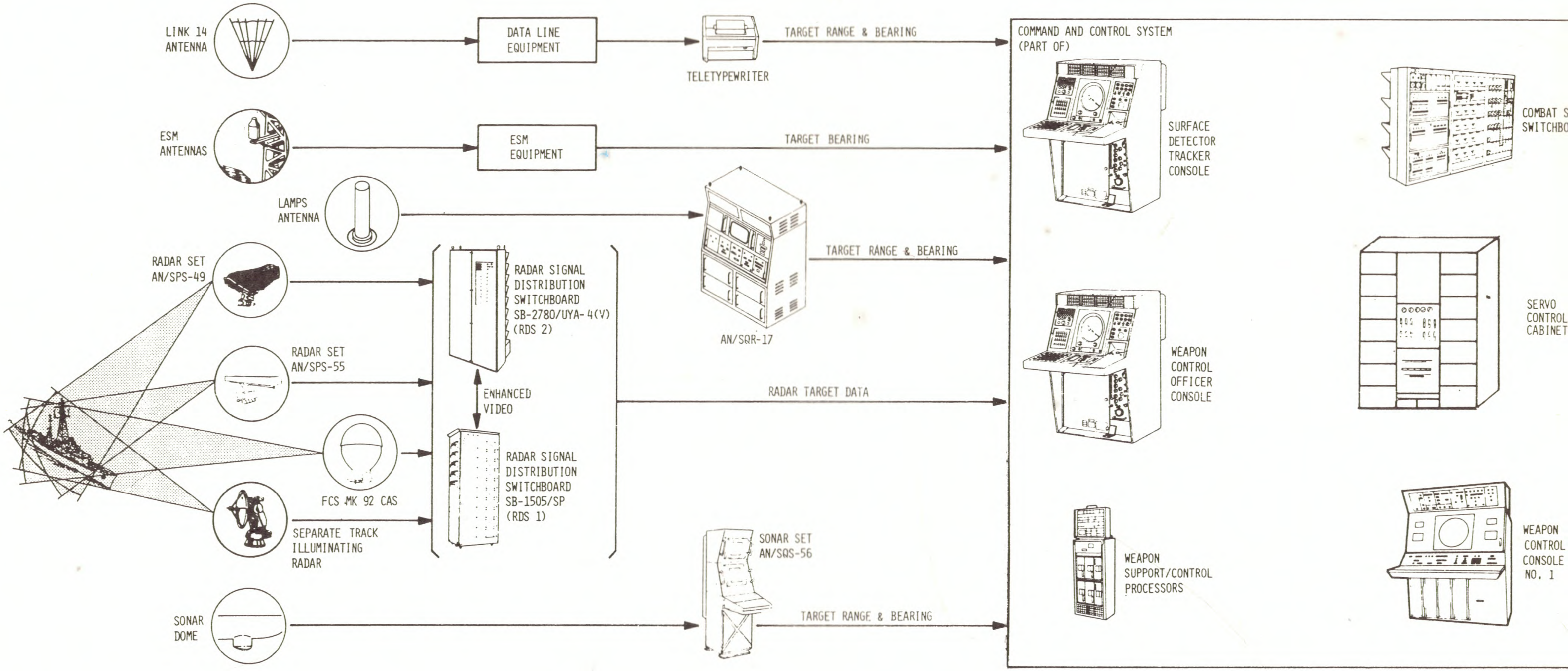

Figure 7-27.—The HWS configuration and int

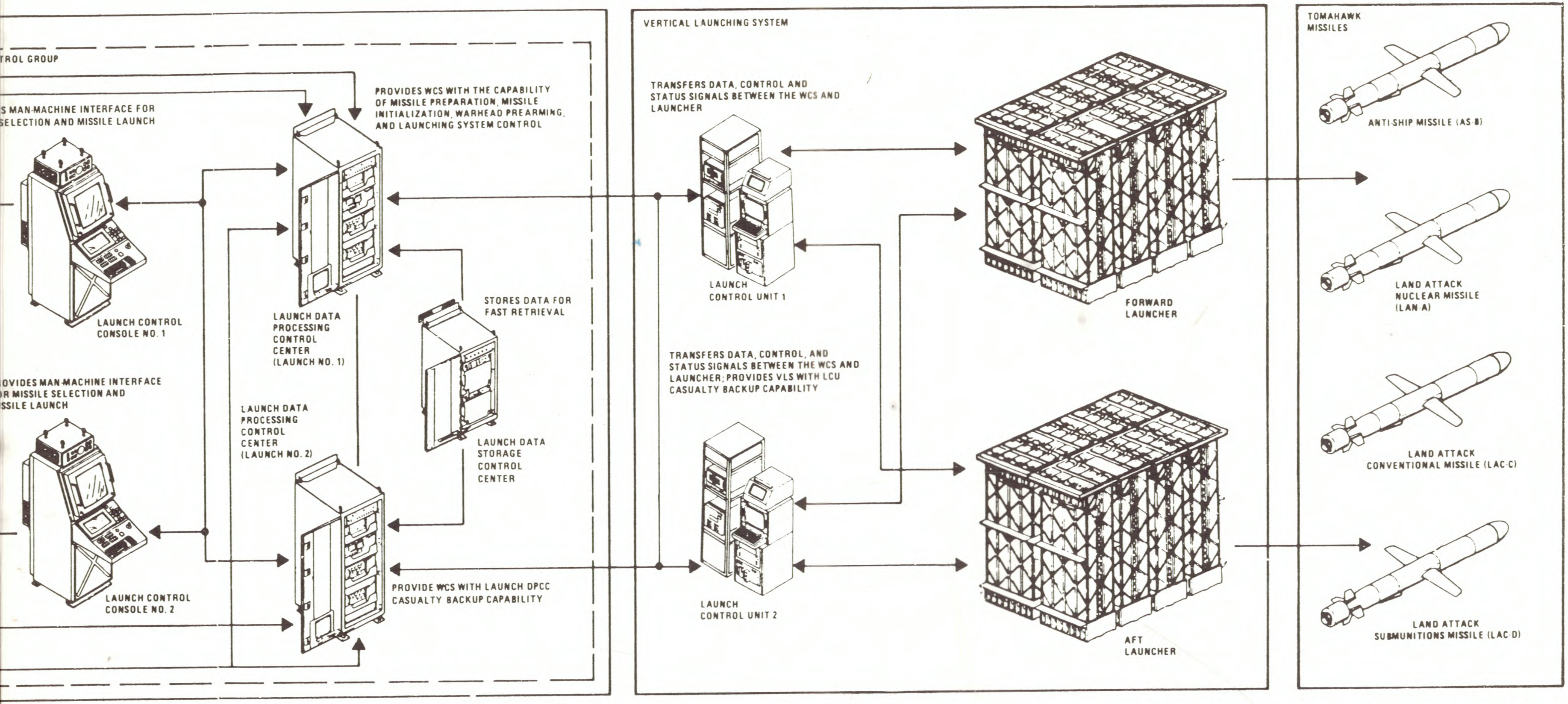
TROL GROUP
S MAN-MACHINE INTERFACE FOR
SELECTION AND MISSILE LAUNCH
PROVIDES WCS WITH THE CAPABILITY OF MISSILE PREPARATION, MISSILE INITIALIZATION, WARHEAD PREARMING, AND LAUNCHING SYSTEM CONTROL
LAUNCH CONTROL CONSOLE NO. 1
LAUNCH DATA PROCESSING CONTROL CENTER (LAUNCH NO. 1)
STORES DATA FOR FAST RETRIEVAL
OVIDES MAN-MACHINE INTERFACE
R MISSILE SELECTION AND
SSILE LAUNCH
LAUNCH DATA PROCESSING CONTROL CENTER (LAUNCH NO. 2)
LAUNCH DATA STORAGE CONTROL CENTER
LAUNCH CONTROL CONSOLE NO. 2
PROVIDE WCS WITH LAUNCH DPCC CASUALTY BACKUP CAPABILITY
VERTICAL LAUNCHING SYSTEM
TRANSFERS DATA, CONTROL AND STATUS SIGNALS BETWEEN THE WCS AND LAUNCHER
LAUNCH CONTROL UNIT 1
FORWARD LAUNCHER
TRANSFERS DATA, CONTROL, AND STATUS SIGNALS BETWEEN THE WCS AND LAUNCHER; PROVIDES VLS WITH LCU CASUALTY BACKUP CAPABILITY
LAUNCH CONTROL UNIT 2
AFT LAUNCHER
TOMAHAWK MISSILES
ANTI-SHIP MISSILE (AS-B)
LAND ATTACK NUCLEAR MISSILE (LAN-A)
LAND ATTACK CONVENTIONAL MISSILE (LAC-C)
LAND ATTACK SUBMUNITIONS MISSILE (LAC-D)

Figure 1-3. TOMAHAWK Weapon System Operational Flow Diagram

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System.

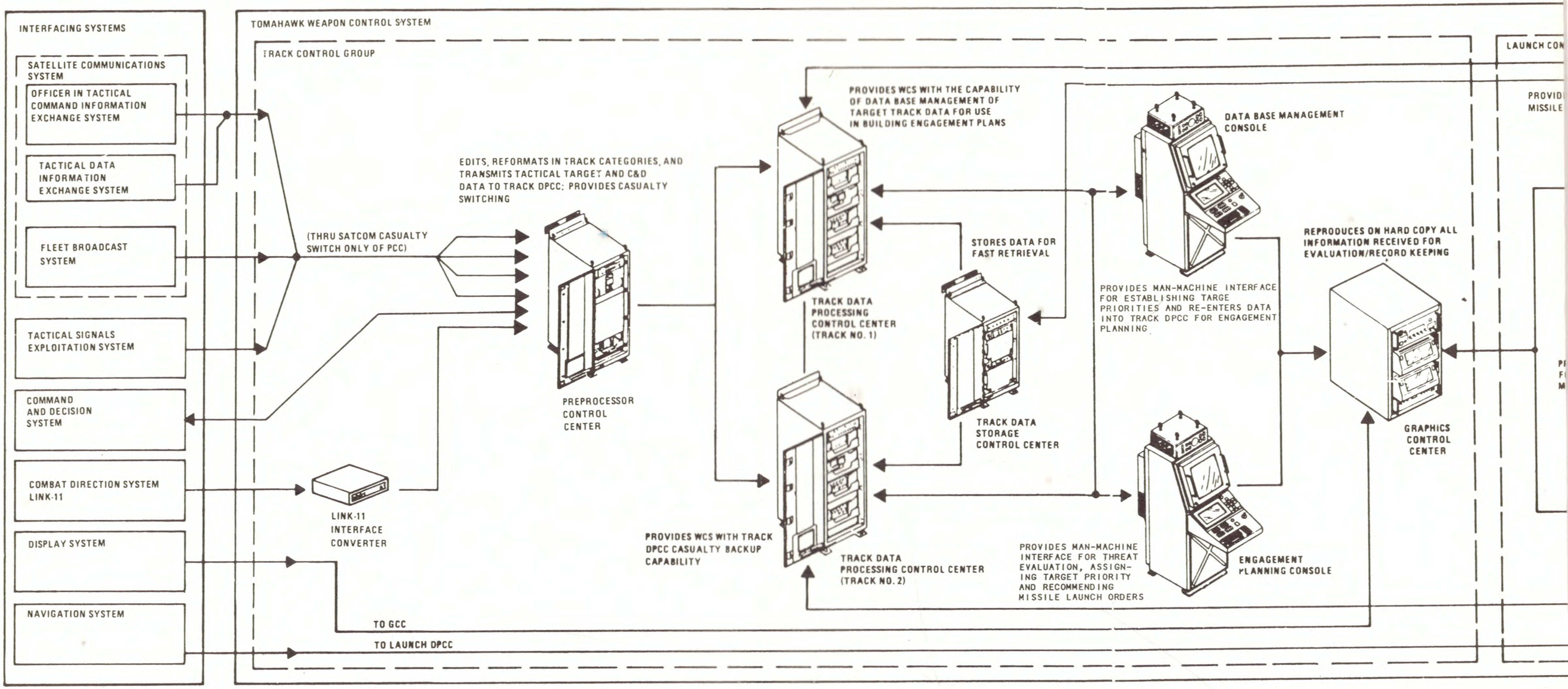
INTERFACING SYSTEMS
SATELLITE COMMUNICATIONS SYSTEM
OFFICER IN TACTICAL COMMAND INFORMATION EXCHANGE SYSTEM
TACTICAL DATA INFORMATION EXCHANGE SYSTEM
FLEET BROADCAST SYSTEM
TACTICAL SIGNALS EXPLOITATION SYSTEM
COMMAND AND DECISION SYSTEM
COMBAT DIRECTION SYSTEM LINK-11
DISPLAY SYSTEM
NAVIGATION SYSTEM
TOMAHAWK WEAPON CONTROL SYSTEM
TRACK CONTROL GROUP
(THRU SATCOM CASUALTY SWITCH ONLY OF PCC)
EDITS, REFORMATS IN TRACK CATEGORIES, AND TRANSMITS TACTICAL TARGET AND C&D DATA TO TRACK DPCC; PROVIDES CASUALTY SWITCHING
PREPROCESSOR CONTROL CENTER
LINK-11 INTERFACE CONVERTER
PROVIDES WCS WITH THE CAPABILITY OF DATA BASE MANAGEMENT OF TARGET TRACK DATA FOR USE IN BUILDING ENGAGEMENT PLANS
TRACK DATA PROCESSING CONTROL CENTER (TRACK NO. 1)
PROVIDES WCS WITH TRACK DPCC CASUALTY BACKUP CAPABILITY
TRACK DATA PROCESSING CONTROL CENTER (TRACK NO. 2)
STORES DATA FOR FAST RETRIEVAL
TRACK DATA STORAGE CONTROL CENTER
DATA BASE MANAGEMENT CONSOLE
PROVIDES MAN-MACHINE INTERFACE FOR ESTABLISHING TARGE PRIORITIES AND RE-ENTERS DATA INTO TRACK DPCC FOR ENGAGEMENT PLANNING
PROVIDES MAN-MACHINE INTERFACE FOR THREAT EVALUATION, ASSIGN-ING TARGET PRIORITY AND RECOMMENDING MISSILE LAUNCH ORDERS
ENGAGEMENT PLANNING CONSOLE
REPRODUCES ON HARD COPY ALL INFORMATION RECEIVED FOR EVALUATION/RECORD KEEPING
GRAPHICS CONTROL CENTER
TO GCC
TO LAUNCH DPCC
LAUNCH CON
PROVID
MISSILE

Figure 7-29.—The Mk 37 Tomahawk Weapon

CHAPTER 8

TARGET DETECTION

Up to now we have centered our discussion on the actual destructive weapon and its associated delivery system. These units rarely, if ever, function alone. They rely on other systems to detect the target and to provide a fire control solution with control orders.

In this chapter we will be describing the target detection process and the types of equipment used to perform this function. The fire control function will be described in the next chapter.

THE DETECTION PROCESS

The modern detection process involves more than the location of possible targets by the ship's sensors. Before sensor information from your ship (or other ships) can be fully used by the weapons system, it must first be processed. Processing involves the extraction of data concerning the target's course, speed, bearing, range, identity as friend or foe, and type of target (air, surface, or subsurface). This information is called **target data** and it is processed by the **Naval Tactical Data System** (NTDS). The NTDS function is central to the modern detection process, so we will describe it first—then we will describe the types of sensors that supply the data to the NTDS.

There are many different detection systems in use today. A discussion of the operation of each one is beyond both the scope and intent of this book. Therefore, in this chapter we will not discuss specific systems; only the general characteristics of the different system types.

NAVAL TACTICAL DATA SYSTEM (NTDS)

The NTDS consists of high-speed computers, data display consoles, communication links, and operational computer programs. This total system functions to collect, analyze, and correlate sensor data to obtain a clear picture of the tactical situation. A good tactical picture includes complete target data on all ships, aircraft, and submarines in the area of concern. This picture is then converted to digital format and supplied to the ship's weapon systems and to other ships over the communications data link.

Figure 8-1 is a simple line drawing that illustrates the NTDS function. The picture

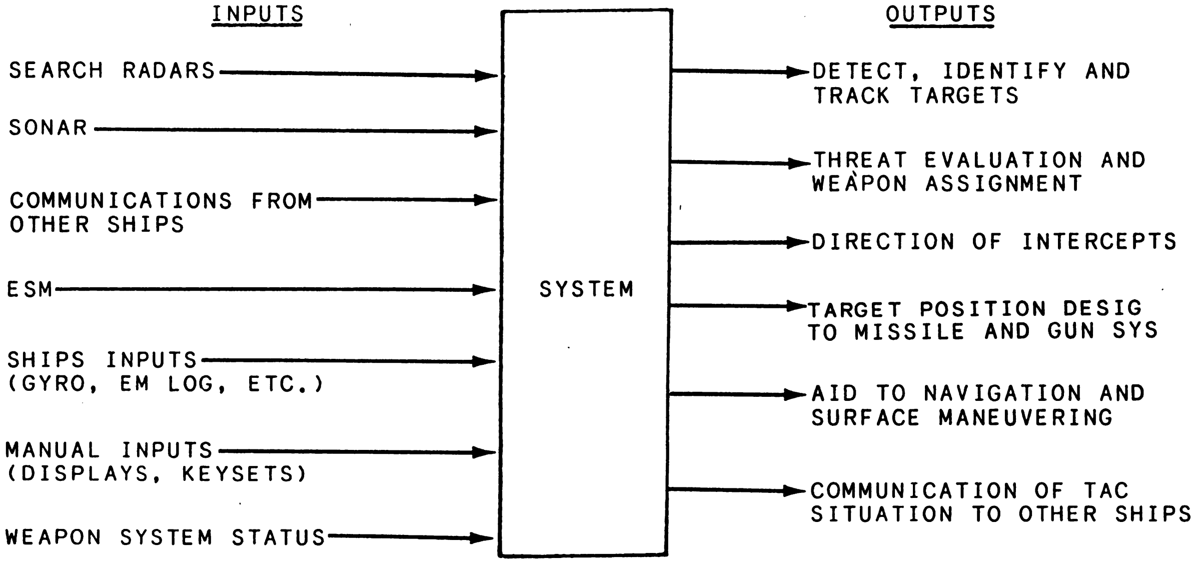
INPUTS
SEARCH RADARS
SONAR
COMMUNICATIONS FROM OTHER SHIPS
ESM
SHIPS INPUTS (GYRO, EM LOG, ETC.)
MANUAL INPUTS (DISPLAYS, KEYSETS)
WEAPON SYSTEM STATUS
SYSTEM
OUTPUTS
DETECT, IDENTIFY AND TRACK TARGETS
THREAT EVALUATION AND WEAPON ASSIGNMENT
DIRECTION OF INTERCEPTS
TARGET POSITION DESIG TO MISSILE AND GUN SYS
AID TO NAVIGATION AND SURFACE MANEUVERING
COMMUNICATION OF TAC SITUATION TO OTHER SHIPS

Figure 8-1.—The NTDS function.

supplied by the NTDS is a "real time" display; it is not a projection but a representation of the tactical situation as it is at that moment, based on available sensor data. Some weapon systems are able to use raw sensor data to engage targets, though this is not the most effective mode of operation. The use of raw data is normally reserved for casualty mode use only.

When two or more ships operate together, one ship will maintain the communications link network. This allows ships in the task force to feed target data into the link for use by the entire group. Each ship in the link will be able to use all of the processed target data from all the other ships in the link. This serves to broaden the tactical picture for the task force commander and for individual commanders as well.

In the past, as with other systems, the NTDS was considered an individual unit instead of a component of the ship's combat system. This is no longer true. Older ships are adopting a one-system philosophy. Newer systems are designed as a single system. The NTDS function is now being performed by the same equipment that performs other functions formerly not associated with NTDS. The AEGIS weapon system is the first system designed under the one system concept. The AEGIS Command and Decision system (C&D) not only performs the NTDS function, but also controls the EW system, IFF challenges, and several other functions as well.

SENSORS

The NTDS collects data from each of the ship's sensors (radar, IFF, ESM, and sonar) over the data link. We have already described the basics of these sensors and some of their operating theory. We will now broaden those descriptions to show what type of information each sensor supplies.

Radar

The Navy uses a variety of search radars to detect surface and air targets. However, they can all be classified as either surface search/navigation, or two-, or/three-coordinate air search radars.

SURFACE SEARCH/NAVIGATION RADARS.—Radar sets such as the AN/SPS-65 are short range, two-coordinate, narrow beam radars capable of good discrimination in range and bearing for surface search and low flying aircraft. They are also valuable because of their ability to detect modern low flying antiship missiles.

THREE-COORDINATE RADARS.—Three-coordinate radars (such as AN-SPS-48 or AN/SPY-1) are normally the primary source of air target information. These radars provide precise air search data consisting of range, bearing, and elevation angle, to the NTDS or weapons direction system (WDS). These radars also provide IFF data (identification, friend or foe). IFF is a subsystem that issues an electronic challenge to aircraft. Depending upon the response, or lack of response from the aircraft, it is determined to be friendly or hostile. The air search data and synchronized IFF interrogation information are displayed on operator consoles in CIC for target engagement evaluation. Electronic counter-countermeasure (ECCM) features improve the display when jamming environments are encountered.

TWO-COORDINATE RADARS.—An alternate source of air target information for a weapon system is a two-coordinate radar. These are the primary means for detection of long-range air targets. These radars, such as the AN/SPS-49, provide coarse range and bearing information and IFF capabilities similar to those of the three-coordinate radars. They do not, however, provide elevation information.

Sonar

In an earlier chapter we described a simple sonar system. It consisted of the elements contained in a shipboard system with a hull mounted transducer. Now, add to that a **towed array** and a **LAMPS** helicopter; both serve as extensions of the shipboard systems sensors.

TOWED ARRAY.—The towed array can be either passive or both active and passive. Both types are lowered into the water on a cable and towed behind the ship. This puts the sensor away from the ship—to minimize ship noise interference. The sensor may be lowered below a thermal layer to eliminate some of the distortion caused by the different water temperatures.

LAMPS.—The LAMPS (Light Airborne Multi-Purpose System) extends the ship's sonar and ASW offensive range. This is accomplished by a helicopter that is equipped with **sonar buoys,** a fire control computer, and air launch torpedoes.

The helo drops the buoys in a pattern to cover a certain area of the ocean. As the buoys descend through the water, they collect and transmit back to the helo any detectable sounds, which are then transmitted over the link. Based on the data collected, the helo and/or the ship may then initiate an attack.

Electronic Support Measures (ESM)

ESM is the passive side of the ship's total electronic warfare capability. Its function is to detect electronic emissions, and aid in the rapid identification of the source platform or weapon. A low flying antiship cruise missile (ASCM), such as our Harpoon, may not be detected by your ship's radar. The first indication you might see is the electronic emissions of the missile's seeker when it initiates the homing phase. This could give you just 90 seconds, or less, to react before the missile strikes your ship.

Modern ESM not only detects the emission, but supplies the operator with a suggestion regarding the source. The operator must then visually verify the accuracy of the suggestion. If he agrees with the evaluation, the push of a button sends the data to the NTDS. Should he disagree, he inputs his evaluation through a manual keyboard.

The LAMPS III helicopter is also equipped with ESM equipment which further extends sensory range. A single ESM unit can only supply target bearing data. The LAMPS III helo, however, can be sent out away from the ship to monitor the same emission, thus allowing a vector of the target's position and range data. Two ships can perform the same maneuver.

Figure 8-2 illustrates the configuration of a modern weapon system aboard an

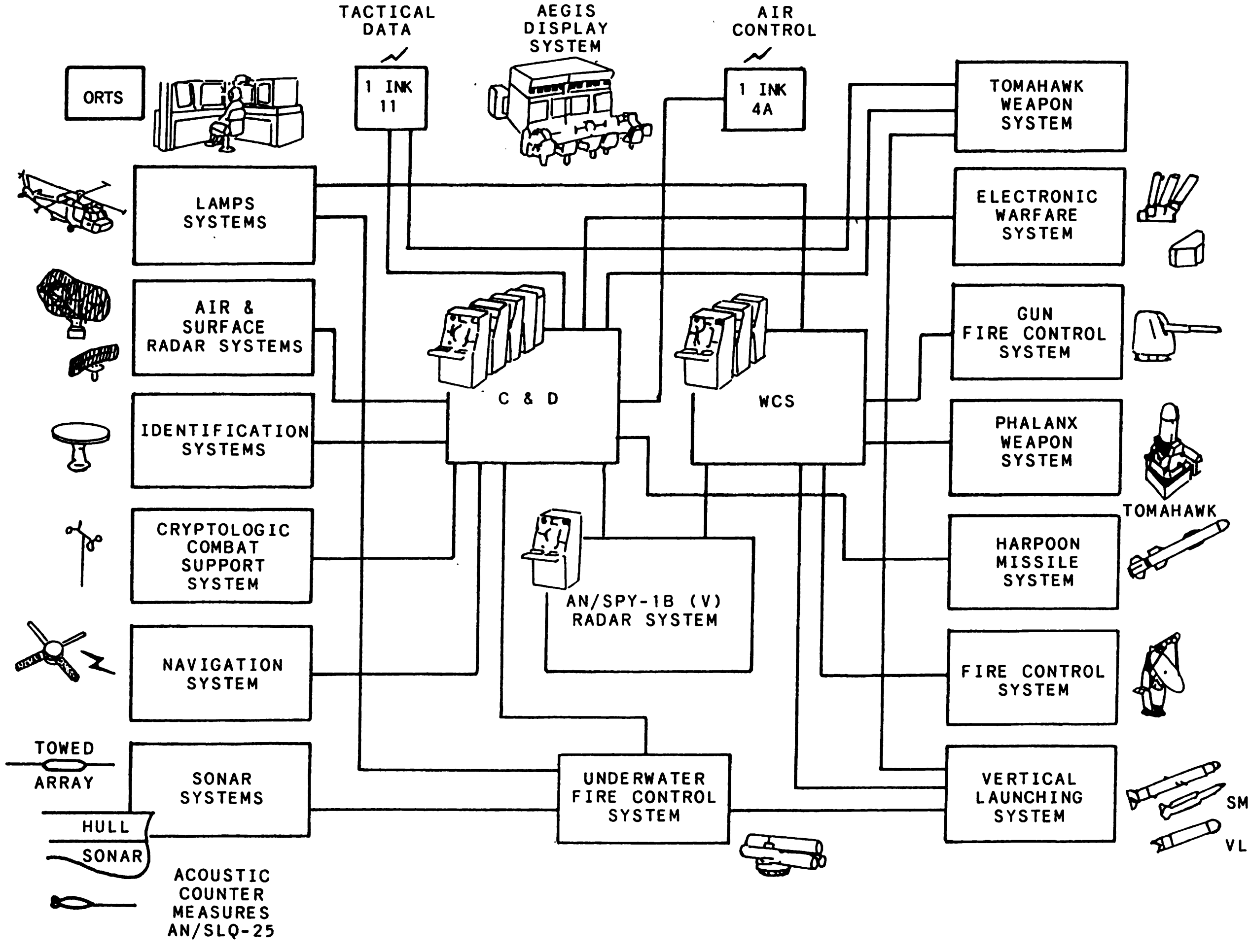

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Figure 8-2.—The AEGIS combat system.

AEGIS-equipped ship. Remember, that the NTDS function is accomplished by the C&D equipment in the AEGIS system.

SUMMARY

This concludes the chapter on detection systems. We have presented the detection function as more than just finding targets with the ship's sensors. We have briefly described how raw data is gathered by the various types of sensors, then processed by the NTDS for use by the weapons system. In the next chapter, we will describe how target information is used by a weapon system to monitor and engage targets.

REFERENCES

Fire Controlman Third Class, NAVEDTRA 10276-1, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1985.

Shipboard Electronics Material Officer, NAVEDTRA 10478-A1, Naval Education and Training Program Development Center, Pensacola, Fla., 1982.

CHAPTER 9

CONTROL SYSTEMS

Thus far we have described three of the four functions performed by a weapon system: detection, delivery, and destruction. We will now describe the control function. As with the other functions, we will first describe the basic components that make up a control system. We will then describe the different elements involved in the fire control problem. Finally we will describe the four major fire control systems now in the fleet.

There are three facets to the control function: (1) determining the threat of a target, (2) assigning the appropriate weapon system to engage the target, and (3) delivering effective fire against the target. These functions are accomplished by the combination of a **weapon direction system** (WDS) and one or more fire control systems.

WEAPON DIRECTION SYSTEM (WDS)

The weapon direction system (WDS), also referred to as **weapon control system** (WCS), functions to schedule, control, and assess the engagement of targets with the ship's weapon systems. WDS consists of a computer set, computer program, and two or more operator consoles.

WDS receives target data from NTDS. Each target is analyzed and assigned a threat priority. The system then assigns a weapon system to engage the highest priority target. Weapon system assignment includes (in the case of a missile engagement) the selection of the number and type of missiles to be fired, as well as which director will be used to track and illuminate the target. In the case of a fully automatic engagement, the system will also initiate missile firing. However, not all systems are capable of fully automatic operation. In all cases, the operator may manually override the system to alter the method of engagement.

Prior to the advent of WDS, each of these functions were performed by the individual action of system operators. Therefore, response time and accuracy were limited to the speed and skill of the operators. As you have seen in previous chapters, a rapid and accurate response is required to defend against the sophisticated modern weapons currently in the world's arsenal. WDS enables the entire engagement (or portions thereof) to be executed rapidly and automatically.

The WDS computer is programmed to prioritize and engage targets that exhibit certain characteristics. In addition to this, the operator consoles can be programmed to include **quick reaction (QR)** zones. These zones determine at what range, and from which direction, approaching targets are automatically engaged. These parameters are constantly updated as the tactical situation changes. QR zones may also be used to help ensure that friendly ships and aircraft are not mistakenly engaged.

FIRE CONTROL SYSTEM ELEMENTS

As described in chapter 1, a basic fire control system consists of a computer, a director with radar, and a stable element. Let us now broaden our description of these elements.

Computer

The definition of a computer is any device capable of accepting data, applying mathematical operations to that data, and obtaining useful information from those operations. A fire control computer accepts target and own-ship's data, processes it, and provides a solution to the fire control problem. Own-ship's data includes course, speed, pitch, and roll. Also included are other variables, such as wind direction and, in the case of guns, projectile initial velocity. This data will be discussed further as we describe the fire control problem later in this chapter.

The fire control solution for a gun engagement consists of gun mount train and elevation orders, fuze setting orders, and, in some cases, gun sight orders. For a missile engagement, the computer supplies launcher train and elevation orders and missile prelaunch programming.

A guided missile, unlike a gun projectile, can change course in flight. Therefore, the missile fire control computer continuously updates the solution for target intercept after the missile is fired. The updated solution is transmitted to the missile, which then corrects its course to intercept the target. This is what is happening during the midcourse phase of an SM-2 missile engagement. The SM-2 engagement also requires target illumination to be scheduled and ordered (during the terminal phase of missile flight). This is also accomplished by the fire control computer.

Director and Radar

The fire control systems director and radar are discussed as a single unit since, once assigned, their combined outputs are the primary source of target information for the fire control computer.

The radar antenna is mounted to the director. Once assigned by the WDS, the director "slews" to the ordered bearing and elevation, where the radar conducts a search for the target. The search is controlled by a subsystem, which moves the director in a predetermined pattern around the ordered position until the radar "acquires" the target. Once acquired by the radar, a subsystem of the radar unit controls the director to keep the radar "locked on" to the target. The system then begins to track the target. While locked on and tracking, the radar and director continuously provide precise target range, bearing, and elevation data to the computer. Radar provides target range, and the director, based on its train angle and the elevation angle of the radar antenna, provides target bearing and elevation data.

Stable Element

A ship, by its very nature, is in constant motion. The weapon systems, especially gun systems, require a stable platform to deliver accurate fire. Since it is impossible to build a ship that is not subject to constant movement, the stable element input is added to the fire control computer. A stable element is a gyroscope mounted to gimbals. Its output provides the computer with a stable horizontal reference from which to compute a fire control solution. Some older systems have their own dedicated stable element, while most newer systems use an input from the ship's gyro.

THE FIRE CONTROL PROBLEM

To deliver accurate fire, a fire control system must consider and compensate for own-ship's movement, gun characteristics, natural forces, and the target's movement. Each compensation involves a different set of variables. This is the essence of the fire control problem.

Own-ship's movement and characteristics involve platform stabilization (stable element), parallax, and interior ballistic considerations. Natural forces are compensated for as exterior ballistics. Target movement involves considering exact target position in reference to your ship, then predicting its future position.

PARALLAX

If guns were physically located at the reference point (the director), projectiles fired from the guns would hit the target without further correction. The guns are, of course, not located at the reference point, but are some distance forward or aft of this point and below it (the director is located high on the superstructure). This puts the gun at a different angle from the target than the director, giving each unit a different line of sight to the target. Unless corrected, this difference will result in large errors in accuracy. The parallax correction is normally accomplished in the fire control computer, but may be corrected by a device attached to the gun.

BALLISTICS

As we said earlier, ballistics is the science of projectile motion. It is divided into two branches, interior and exterior ballistics. Interior ballistics is the study of projectile motion while inside the gun. Exterior ballistics pertain to the projectile motion after it leaves the gun.

Interior Ballistics

The speed at which a projectile is traveling at the instant it leaves the gun bore, is known as **initial velocity**. The initial velocity of a projectile must be known to predict its trajectory. Initial velocity is determined by the gun, the projectile, and the propelling charge. Projectiles and propelling charges are standardized. This means that all size, weight, and shape variations are predetermined. The only variables left to consider are the condition of the gun and the temperature of the propelling charge. The propelling charge temperature is determined by averaging the powder magazine temperatures for the previous 3 days.

Figure 9-1 illustrates the components of a gun. When a projectile and propelling charge are loaded into the gun, the projectile rotating band engages the rifling in the gun bore. The rotating band forms a seal at the forcing cone. When the gun is fired, the expanding gases from the burning propellant push the projectile through the bore and out the muzzle. As the projectile passes through the bore, the twisted rifling imparts a spin to the projectile which stabilizes it in flight.

Each firing wears on the interior surfaces of the gun. This erosion results in a gradual enlargement of the bore. It begins at the rear of the bore, and extends further down the bore as the gun is used. As the bore enlarges, the seal becomes less effective, resulting in a slower initial velocity.

Data from the annual star gauge inspection and from the regular Projectile Seating and Distance Gauge (PSDG) tests (described in chapter 5) is used to compute initial velocity (iv). The determined initial velocity is then entered into the fire control computer for consideration in the final fire control solution.

Exterior Ballistics

Exterior ballistics start with a projectile traveling at a known speed (initial velocity) and in a known direction. This direction, called the **Line of Fire** (LOF), coincides with the centerline axis of the gun bore. Once the projectile leaves the gun, you have no further control over its trajectory. Natural forces such as gravity, air, wind, drift, and the Earth's rotation, act on the projectile in flight to alter its trajectory. Therefore, to hit a target, it is necessary to compensate for the effects of these forces by offsetting the guns LOF prior to firing. For example, if it is known that a projectile is going to drift right, the gun should be trained to the left. If it is known that a projectile is going to curve downward, the gun should be elevated.

The ultimate purpose of a (gun) fire control system is to (1) find the correct position for the gun barrel to make the projectile fall where desired, and (2) to put the gun in that position.

GRAVITY.—Gravity is a continuous attracting force, acting perpendicular to the surface of the Earth, which tends to pull all objects toward the Earth. Without gravity, a projectile (fired in a vacuum) would continue to travel in the direction it was fired until something interfered with its flight.

Gravity acts on a fired projectile causing it to begin to fall as soon as it leaves the muzzle of the gun. The projectile, however, is traveling forward and falling at the same time. The projectile has two natural forces acting on it: (1) inertia, and (2) the pull of gravity. The path of the projectile, as a result of these two forces, is a curved trajectory.

AIR.—When a projectile is traveling through the air, it takes a different path from the one it would follow in a vacuum. In a vacuum, with gravity as the only retarding factor, a projectile's **Angle of Departure** and **Angle of Fall** would be identical (fig. 9-2). The **Maximum Ordinate** would be in the exact center of the trajectory.

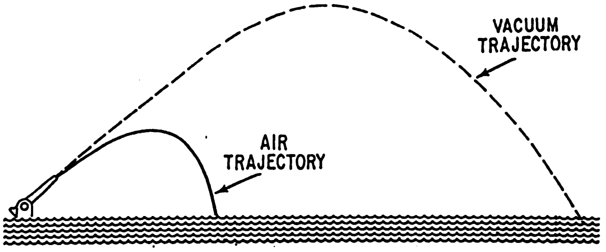

Figure 9-2.—Vacuum and air trajectories for the same elevation angle.

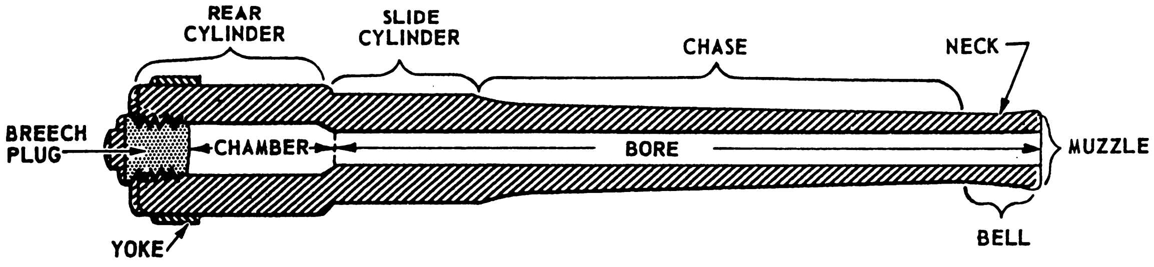

Figure 9-1.—Cross section of a gun.

Air resists the motion of a body passing through it. This resistance is a form of friction, which slows the movement of the body. The result is that a certain amount of velocity is being lost for each second of projectile flight. The longer the projectile travels through the air, the slower it goes. Notice the steepness of the descending curve and the location of the maximum ordinate in the air trajectory. These characteristics, as well as the greatly reduced range, are due to air resistance.

The density of the air determines the amount of resistance the projectile will experience. **Air Density** depends on temperature and barometric pressure, both of which are changing all the time. Dense air will slow a projectile more than thin air. Density also varies at different altitudes, which further complicates the equation.

WIND.—The effect of wind on a projectile in flight is obvious. Depending upon its force and the direction it is coming from, wind can cause a projectile to fall short, over shoot, or fall to the left or right of the target. As with air density, the longer a projectile is in flight, the more it will be affected by wind. The size of a projectile is also a factor: the larger the projectile, the more it will be affected.

True wind is used in all fire control calculations. If the wind is blowing along the line of fire, either with or against the projectile, it is called **range wind** (fig. 9-3). If the wind is blowing at right angles to the line of fire, it is called **cross wind**. Range wind is compensated for by increasing or decreasing gun elevation angle. Corrections for cross wind are made to the guns train angle.

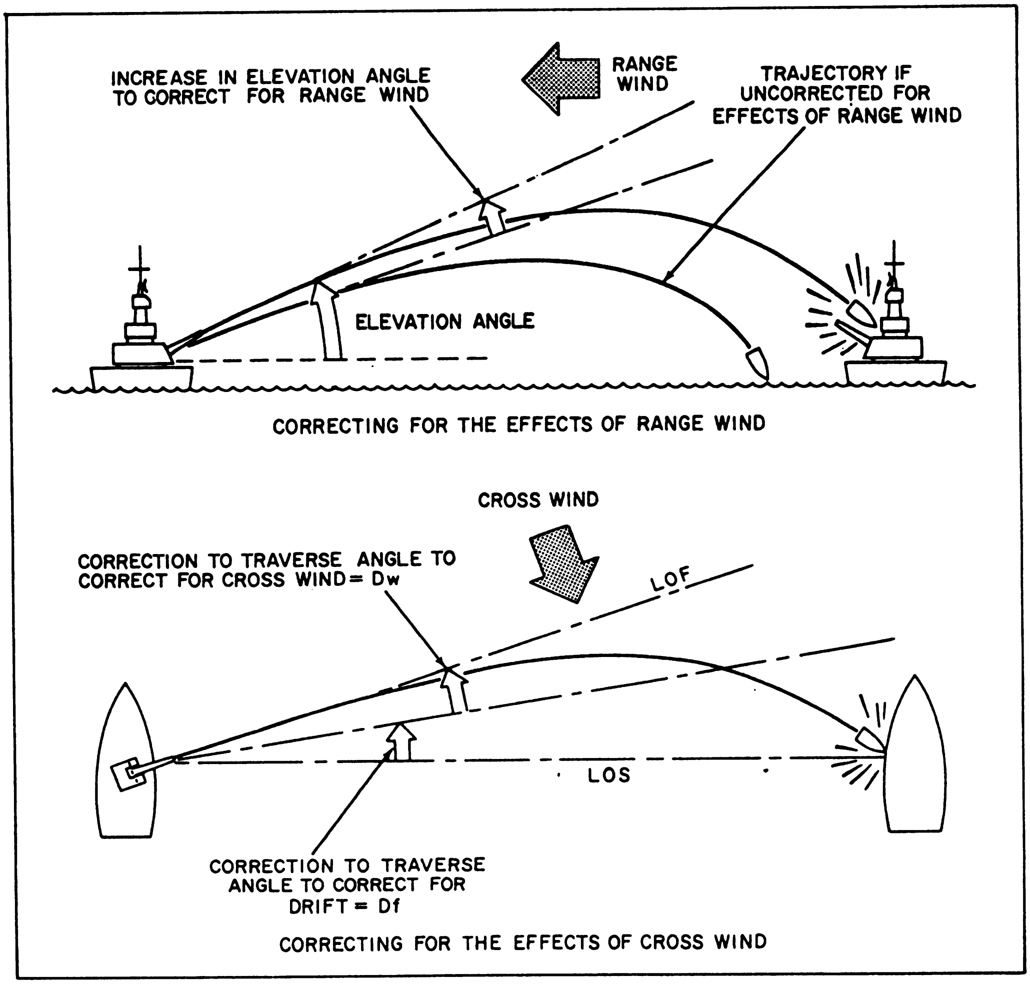
INCREASE IN ELEVATION ANGLE TO CORRECT FOR RANGE WIND
RANGE WIND
TRAJECTORY IF UNCORRECTED FOR EFFECTS OF RANGE WIND
ELEVATION ANGLE
CORRECTING FOR THE EFFECTS OF RANGE WIND
CROSS WIND
CORRECTION TO TRAVERSE ANGLE TO CORRECT FOR CROSS WIND = Dw
LOF
LOS
CORRECTION TO TRAVERSE ANGLE TO CORRECT FOR DRIFT = Df
CORRECTING FOR THE EFFECTS OF CROSS WIND

Figure 9-3.—Correcting for the effects of wind.

Normally, however, the wind will be at some angle to the line of fire. In that case, the true wind must be broken down to the range and cross wind components (fig. 9-4). This calculation allows for the realized effect of the wind in each direction.

DRIFT.—Naval guns are rifled to give a spinning motion to the projectile. The spinning projectile assumes the properties of a gyroscope. The gyroscopic actions tend to keep the projectile pointed along the trajectory, and prevent it from tumbling. This makes the projectile almost rigid in its trajectory and ensures it will land point first. It is this property of rigidity that makes the projectile predictable.

In addition to this useful effect, gyroscopic action causes the harmful effect of **drift** (fig. 9-5). Notice that the effect increases with range. Drift is always to the right in a gun with right hand rifling (the twist of the rifling is to the right from the chamber to the muzzle).

EARTH'S ROTATION.—In our discussion so far, we have assumed that the earth is flat and does not rotate. For ranges up to about 20,000 yards or so, this does not seriously affect our fire control solution. At longer ranges, however, the earth's rotation has a serious affect.

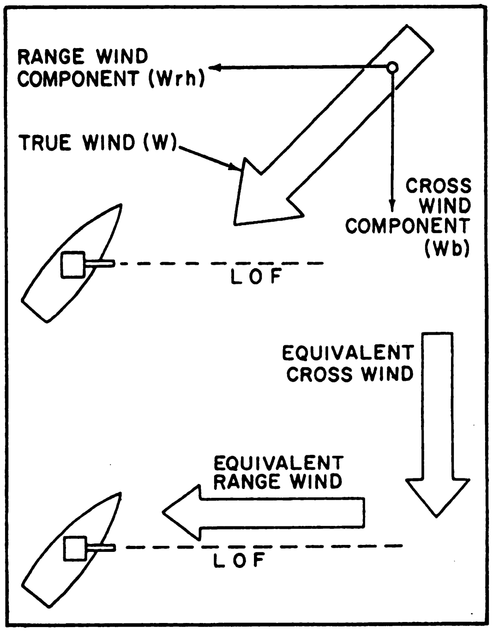

Figure 9-4.—Reading true wind.

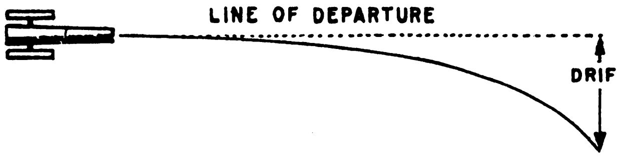

Figure 9-5.—Effect of drift.

An object in motion above the surface of the earth tends to turn toward the right in the Northern Hemisphere and toward the left in the Southern Hemisphere. Corrections are made to the left or right accordingly. The correction is only made on guns larger than 5 inches.

Frames of Reference

A frame of reference is a system of lines, angles, and planes, within which target position can be measured and lead angles computed. A position can be described only by relating it to a known reference point. A reference frame has a point, called the **point of origin** or reference point, from which all measurements are made.

There are two frames of reference used by fire control systems. One is rigidly attached to the ship, while the other is considered rigidly attached to the surface of the earth. The ship frame of reference has its point of origin built into the fire control system. All measurements are made from this point. This point is unstablized, subject to the ship's pitch and roll. The earth frame of reference is a horizontal plane established by the stable element; independent of the ship's pitch and roll.

LINES.—Given the effects of exterior ballistics, two lines are required. One line, called the **Line of Sight** (LOS), is used to establish the present location of the target; the second line, called the **Line of Fire** (LOF), is used to establish the position of the gun bore with respect to the LOS. The LOS is the primary reference from which the offsets are made to establish the LOF.

LEAD ANGLES.—Two lead angles are considered in the fire control problem; **sight angle**

and **sight deflection** (fig. 9-6). Sight angle is the difference between the LOF and the LOS, measured on the plane perpendicular to the trunnion axis. Sight deflection is the angle that the plane through the gun bore is deflected left or right from the LOS.

REFERENCE PLANES.— Reference planes are flat surfaces that may extend in all directions to infinity. Normally, these planes are pictured with boundaries equal to the range of the fire control problem as shown in figure 9-7.

The fire control system establishes target location as a point on a plane using the same three-coordinate system described in chapter 8. Once the target's position, speed, and direction of travel are determined, its future position can be accurately predicted.

The steps in the solution of the fire control problem can be described as follows:

1. Determining present target location in relation to own ship
2. Predicting future target position in relation to own ship
3. Stabilizing the system
4. Calculating the required correction to the gun or launcher train and elevation orders
5. Transmitting the data to the delivery device

We have attempted to cover the basic elements involved in the fire control problem. Our descriptions may seem slanted toward the gun problem. This is because the gun solution has more elements to consider (all interior and some exterior ballistics). Also, each element must be compensated for exactly, because once fired, a gun projectile cannot be redirected. The entire problem is, however, much more complex than the general description we have provided. For a more detailed description, see *Fire Controlman Third Class (FC3),* NAVEDTRA 10276.

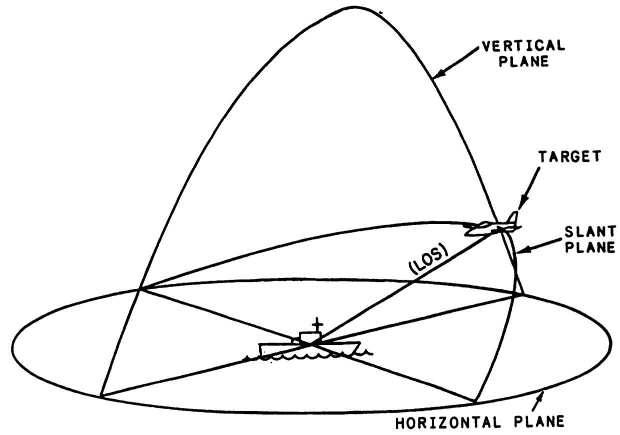

Figure 9-7.—Reference planes.

FIRE CONTROL SYSTEMS

There are several fire control systems (FCS) currently in use aboard U.S. Navy ships. The most modern of these is the AEGIS Weapon System. AEGIS is a complete system, incorporating all the elements of a weapon system. It is included here in the control section because of the unique advancements it employs in the integration of control systems. We will provide a basic description of the AEGIS system, the Mk 34 GWS, the

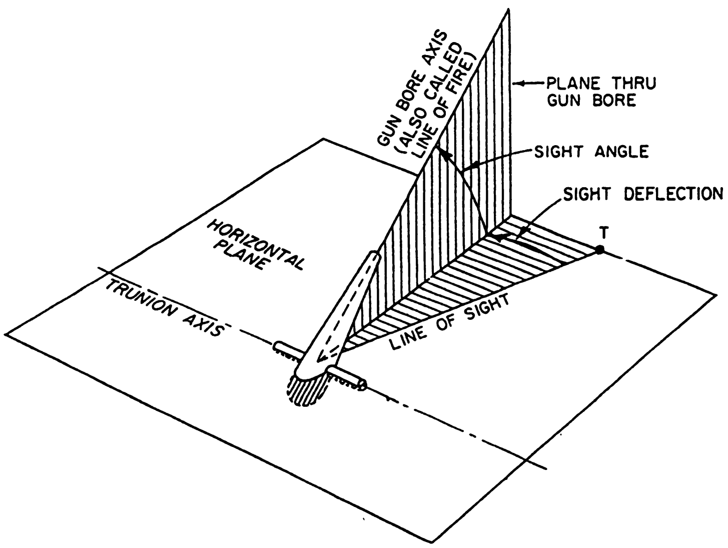

Figure 9-6.—Lead angles in a surface problem.

Mk 86 GFCS, and the Mk 92 FCS. These systems represent the most modern fire control capabilities in the world and should be in our inventory well into the next century.

AEGIS WEAPON SYSTEM

The AEGIS Weapon System is a fast reaction, high performance, computer controlled system that uses a multipurpose radar to detect contacts in all directions. It is the only system in the free world that can detect, tract, and engage multiple threats, while maintaining continuous surveillance from horizon to zenith. AEGIS is the first system in the Navy to be capable of fully automatic reaction to intense air warfare.

AEGIS is equipped with embedded computer-controlled tests which continuously monitor the system to detect equipment failures. When a failure is detected, the system automatically reconfigures, using backup systems to keep the system operational. These features make AEGIS the most reliable system in the fleet.

The AEGIS Weapon System Mk 7, as illustrated in figure 9-8, is made up of the following nine elements:

1. AN/SPY-1 Radar
2. Command and Decision System (C&D)
3. Weapons Control System (WCS)
4. Fire Control System (FCS)

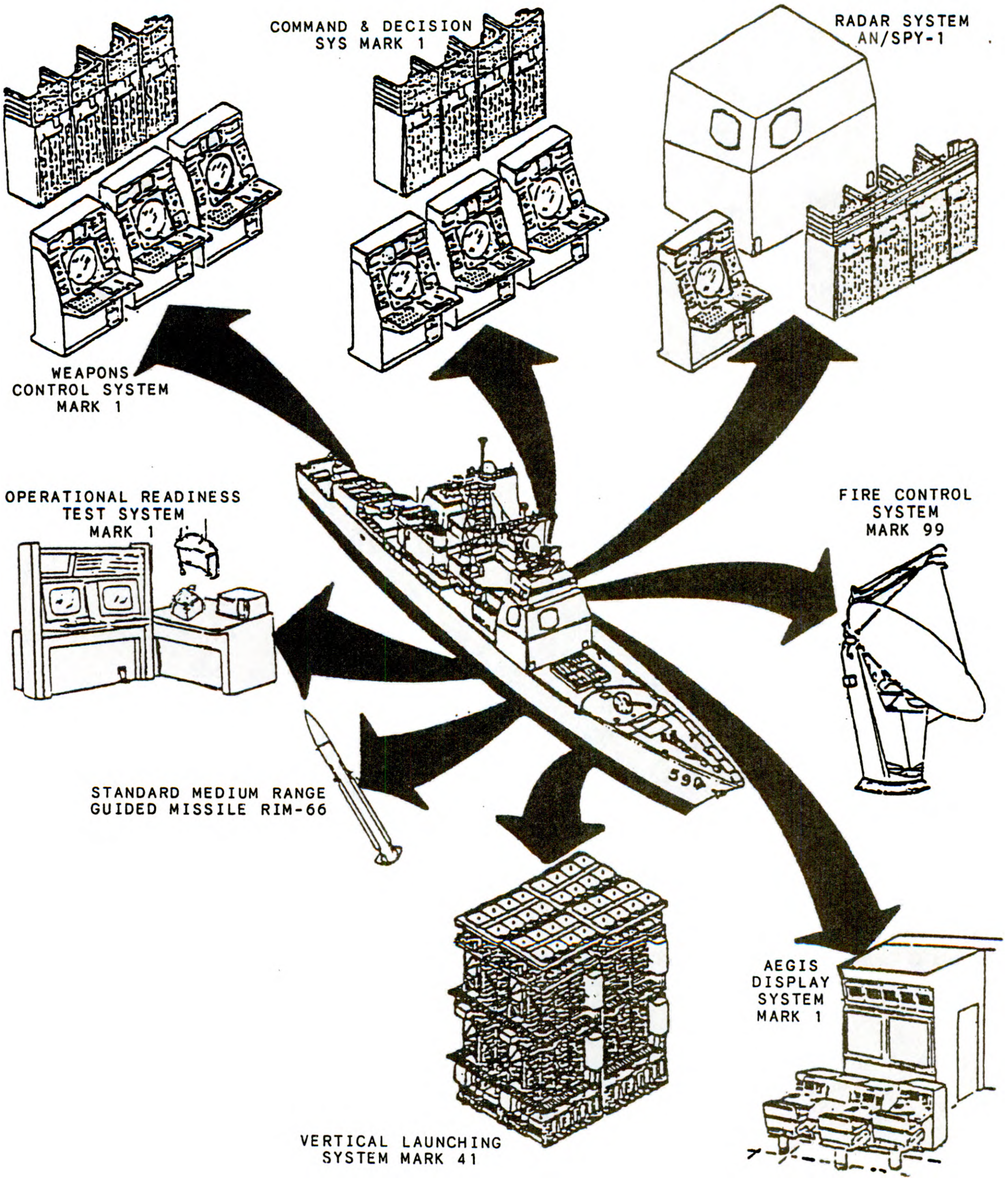
COMMAND & DECISION SYS MARK 1
RADAR SYSTEM AN/SPY-1
WEAPONS CONTROL SYSTEM MARK 1
OPERATIONAL READINESS TEST SYSTEM MARK 1
FIRE CONTROL SYSTEM MARK 99
STANDARD MEDIUM RANGE GUIDED MISSILE RIM-66
AEGIS DISPLAY SYSTEM MARK 1
VERTICAL LAUNCHING SYSTEM MARK 41

Figure 9-8.—AEGIS Weapon System Mk 7 major elements.

5. GMLS Mk 26 or VLS Mk 41
6. Standard Guided Missile
7. AEGIS Display System (ADS)
8. Operational Readiness Test System (ORTS)
9. AEGIS Combat Training System (ACTS)

Of the nine elements, seven have sophisticated computer programs for operation, control, and interface. These are the AN/SPY-1, C&D, WCS, FCS, ADS, ACTS, and ORTS. Operators manage and control the C&D, WCS, and SPY programs with doctrine statements. This allows the operator to define parameters that control the computer program for the tactical situation. Doctrine statements define automatic actions for targets meeting specific conditions.

A general description of each of the major elements of the AEGIS Weapon System is offered here. Since the Standard missile and both launchers were discussed in chapters 6 and 7 respectively, they will not be covered here.

AN/SPY-1 Radar System

The AN/SPY-1 Radar System is the primary search and track radar for AEGIS-equipped ships. It is a multifunction, phased array radar, capable of three-dimensional surveillance, while simultaneously providing fire control tracking for hundreds of air and surface targets in clear and ECM environments. In addition to search and track, it provides midcourse guidance to the Standard missile (SM-2).

Command and Decision (C&D)

The Command and Decision System (C&D) is a manned computer and display complex that coordinates and controls the AEGIS mission. C&D operators manage automatic combat information center (CIC) operations related to:

1. Air, surface, and subsurface engagements
2. Electronic Warfare System control
3. Data link control
4. IFF challenges
5. User defined information alerts
6. Weapon tight zones

Weapon Control System (WCS)

The Weapon Control System (WCS) schedules, controls, and assesses all air, surface, and subsurface engagements. It is the interface between C&D and the delivery systems (gun mounts, missile launchers, CIWS, etc.).

Fire Control System (FCS)

The Fire Control System (FCS) provides illumination control for Standard missile engagements. WCS assignment orders and AN/SPY-1 target data make a designation source for the FCS illuminators. The FCS consists of four AN/SPG-62A radar sets. This permits the illumination of multiple targets simultaneously.

AEGIS Display System (ADS)

The AEGIS Display System (ADS) is a computer-controlled display complex that provides various pictures and information of the tactical environment. With ADS, commanders can observe and control a graphic representation of selected tracks, coastal maps, weapons release zones, and specific warfare environments. After entry of selected information, the displays are automatically updated in regard to own-ship's position. ADS receives all track information from the C&D system.

Operational Readiness Test System (ORTS)

The Operational Readiness Test System (ORTS) is a computer-controlled test and monitor system that performs automatic fault detection, fault isolation, status monitoring, and system reconfiguration. When a fault occurs, ORTS automatically assesses and displays the highest level of system impact. Through a keyboard, the operator can initiate tests, evaluate system performance, and load programs into the various AEGIS computers. When conducting tests, the system uses embedded test equipment throughout the system to measure voltages, analyze data, and measure power and phase.

AEGIS Combat Training System (ACTS)

The AEGIS Combat Training System (ACTS) enables shipboard personnel to conduct highly integrated multifacet warfare training scenarios for their CIC teams. It also provides the capability to record and printout specific training events for self-evaluation.

All these elements form the core of the AEGIS Combat System (ACS). The ACS also integrates and controls the following elements:

1. Harpoon Weapon System
2. Gun Weapon System
3. LAMPS Helicopter
4. Electronic Warfare System
5. Sonar
6. Air and Surface Search Radars
7. Navigation System

The complete integration of all these systems serves to enhance the capability of a ship to simultaneously engage and defeat numerous multiwarfare threats.

MK 34 GUN WEAPON SYSTEM

The MK 34 Gun Weapon System (GWS) is a departure from past gun fire control systems. In line with the "one system" concept, the Mk 34 GWS is designed as a fully integrated subsystem of the AEGIS combat system to include the fire control computer, gunmount, and sight. The Mk 34 GWS receives target engagement orders from the AEGIS command and decision (C&D) system. It receives target data from shipboard sensors, performs ballistic calculations, and generates gun control orders. Digital target data is provided primarily by the AN/SPY-1 Phased Array Radar System, with the AN/SPS-67 Surface Search Radar serving as the secondary source of target data. Figure 9-9 illustrates the functional interface of the Mk 34 GWS with other elements of the combat system.

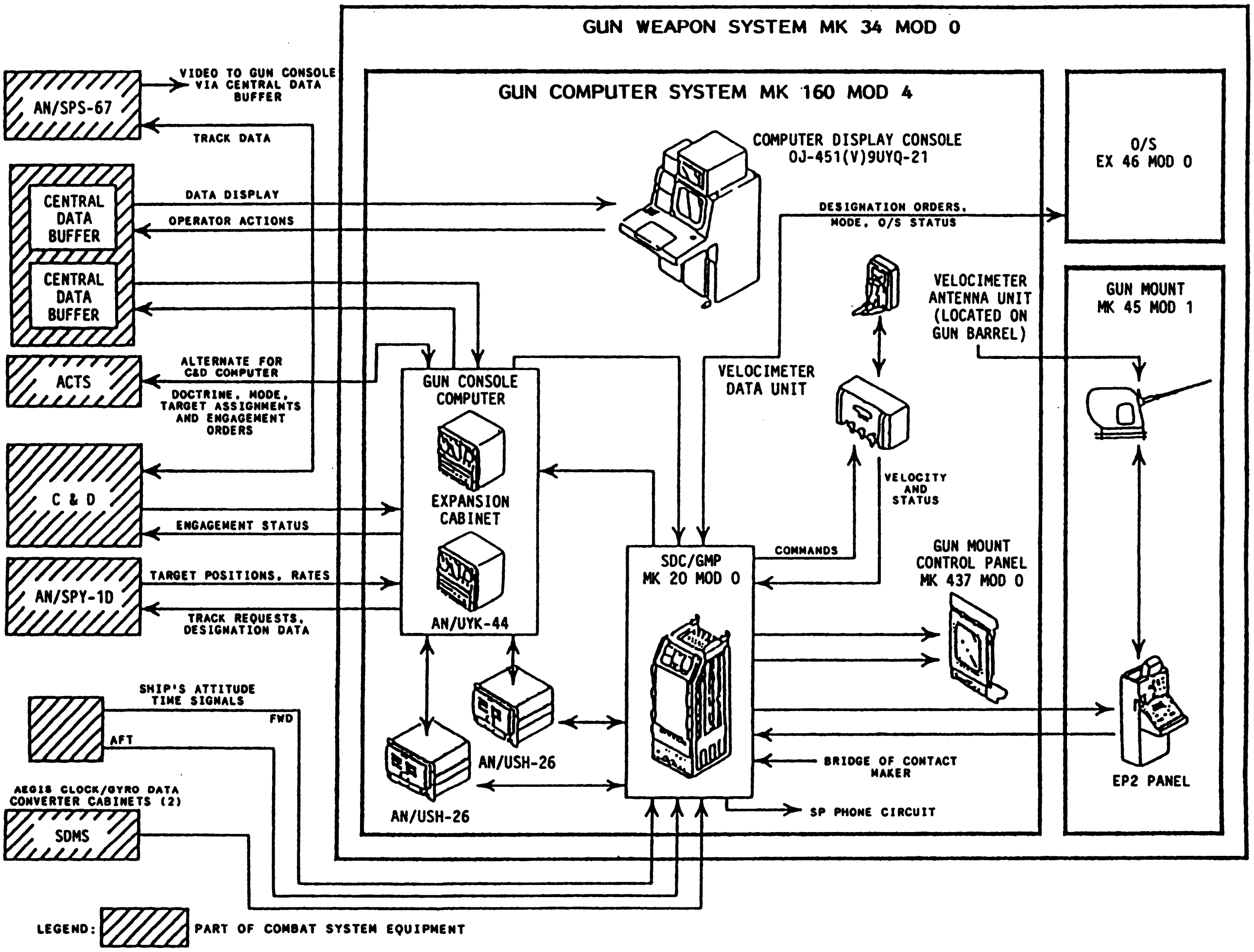
GUN WEAPON SYSTEM MK 34 MOD 0
GUN COMPUTER SYSTEM MK 160 MOD 4
AN/SPS-67
VIDEO TO GUN CONSOLE VIA CENTRAL DATA BUFFER
TRACK DATA
CENTRAL DATA BUFFER
DATA DISPLAY
OPERATOR ACTIONS
CENTRAL DATA BUFFER
ACTS
ALTERNATE FOR C&D COMPUTER
DOCTRINE, MODE, TARGET ASSIGNMENTS AND ENGAGEMENT ORDERS
C & D
ENGAGEMENT STATUS
AN/SPY-1D
TARGET POSITIONS, RATES
TRACK REQUESTS, DESIGNATION DATA
SHIP'S ATTITUDE TIME SIGNALS
FWD
AFT
AEGIS CLOCK/GYRO DATA CONVERTER CABINETS (2)
SDMS
COMPUTER DISPLAY CONSOLE OJ-451(V)9UYQ-21
DESIGNATION ORDERS, MODE, O/S STATUS
O/S EX 46 MOD 0
VELOCIMETER ANTENNA UNIT (LOCATED ON GUN BARREL)
GUN MOUNT MK 45 MOD 1
GUN CONSOLE COMPUTER
EXPANSION CABINET
AN/UYK-44
VELOCIMETER DATA UNIT
VELOCITY AND STATUS
COMMANDS
SDC/GMP MK 20 MOD 0
GUN MOUNT CONTROL PANEL MK 437 MOD 0
AN/USH-26
AN/USH-26
BRIDGE OF CONTACT MAKER
SP PHONE CIRCUIT
EP2 PANEL
LEGEND:
PART OF COMBAT SYSTEM EQUIPMENT

Figure 9-9.—Functional interface of the Mk 34 GWS.

The Mk 34 Gun Weapon System (GWS) will be installed on all new construction AEGIS ships, beginning with the DDG-51 Class destroyer. The system consists of a Mk 160 gun computer system (GCS), a 5"/54 Mk 45 gun system, and an EX 46 optical sight. The following is a brief description of each of these components except for the 5"/54 Mk 45 gun, which was described in chapter 5.

Mk 160 Gun Computer System

The Mk 160 Gun Computer System (GCS) receives target data from shipboard sensors to compute a ballistic solution. From this ballistic solution, it provides gun orders and selects projectile types. The GCS also generates the fire order to the gun mount. The Mk 160 GCS consists of the following elements:

- Gun Console Computer (GCC)
- Computer Display Console (CDC)
- Recorder-Reproducer
- Signal Data Converter/Gun Mount Processor (SDC/GMP)
- Gun Mount Control Panel (GMCP)
- Velocimeter

GUN CONSOLE COMPUTER.—The Gun Console Computer (GCC) serves as the primary interface between the GWS and the AEGIS C&D System and combat system sensors. It acts as a filter for target data, passing data for the selected target to the Signal Data Converter/Gun Mount Processor.

COMPUTER DISPLAY CONSOLE.—The Computer Display Console (CDC), also known as the Gun Console (GC), serves as the operator-to-GCS interface for providing target/system status and data entry displays. It also permits manual selection of the engagement mode and type of ammunition, queuing and engaging targets, entering ballistic data, and adjusting fire.

RECORDER-REPRODUCER.—The Recorder-Reproducer is a standard lightweight digital tape storage subsystem using a tape cartridge medium. The GCS uses two of these units to load operational programs, record, and retrieve system operational data.

SIGNAL DATA CONVERTER/GUN MOUNT PROCESSOR.—The Signal Data Converter/Gun Mount Processor (SDC/GMP) consists of two primary segments—the Signal Data Converter (SDC) and the Gun Mount Processor (GMP). Both are contained in a single watertight cabinet located in the gun mount. The GMP computes two ballistic solutions for the target being engaged, based on filtered target data, control commands, and other ship's information. The GMP converts ballistic solutions into gun orders, which are transmitted to the gun mount by the SDC.

GUN MOUNT CONTROL PANEL.—The Gun Mount Control Panel (GMCP) is used to monitor and display GCS and GWS status in the normal modes of operation. The primary function of the GMCP, however, is to provide a casualty mode means of target data entry into the SDC/GMP should data not be availible from the gun console.

VELOCIMETER.—The velocimeter is a doppler radar system used to measure projectile initial velocity (IV). The IV data is passed digitally to the GMP to update/correct ballistic computations. The velocimeter antenna is mounted directly to the gun above the barrel.

EX 46 Optical Sight

While still in development at this writing, some information is availible on the EX 46 optical sight (OS). The sight is described as a stabilized imaging sensor. The OS will supplement the ship's sensors coverage, allowing the operator to detect and track surface targets, support the engagement of counter-battery threats, and act as a safety check sight during gun operations.

Mk 86 GFCS

The Mk 86 GFCS is a shipboard, digitally controlled system that directs gunfire against surface, shore, and air targets. The system is designed to control the 5"/54 Mk 45 rapid-fire gun mount currently found aboard various platforms, including the DD-963, DDG-993, CG-47, CGN-36, CGN-38, and LHA-1 class ships.

Variations of the system integrate it with the ship's missile FCS. The missile FCS, in these cases, can use the Mk 86 system to supply air target tracking and CWI for control of SM-1 missile engagements. Other improvements enable the system to control SM-2 engagements. In this text, however, we will discuss only the gun control function of the system.

Refer to figure 9-10 as we describe the major components of the Mk 86 Mod 10 GFCS. For ease

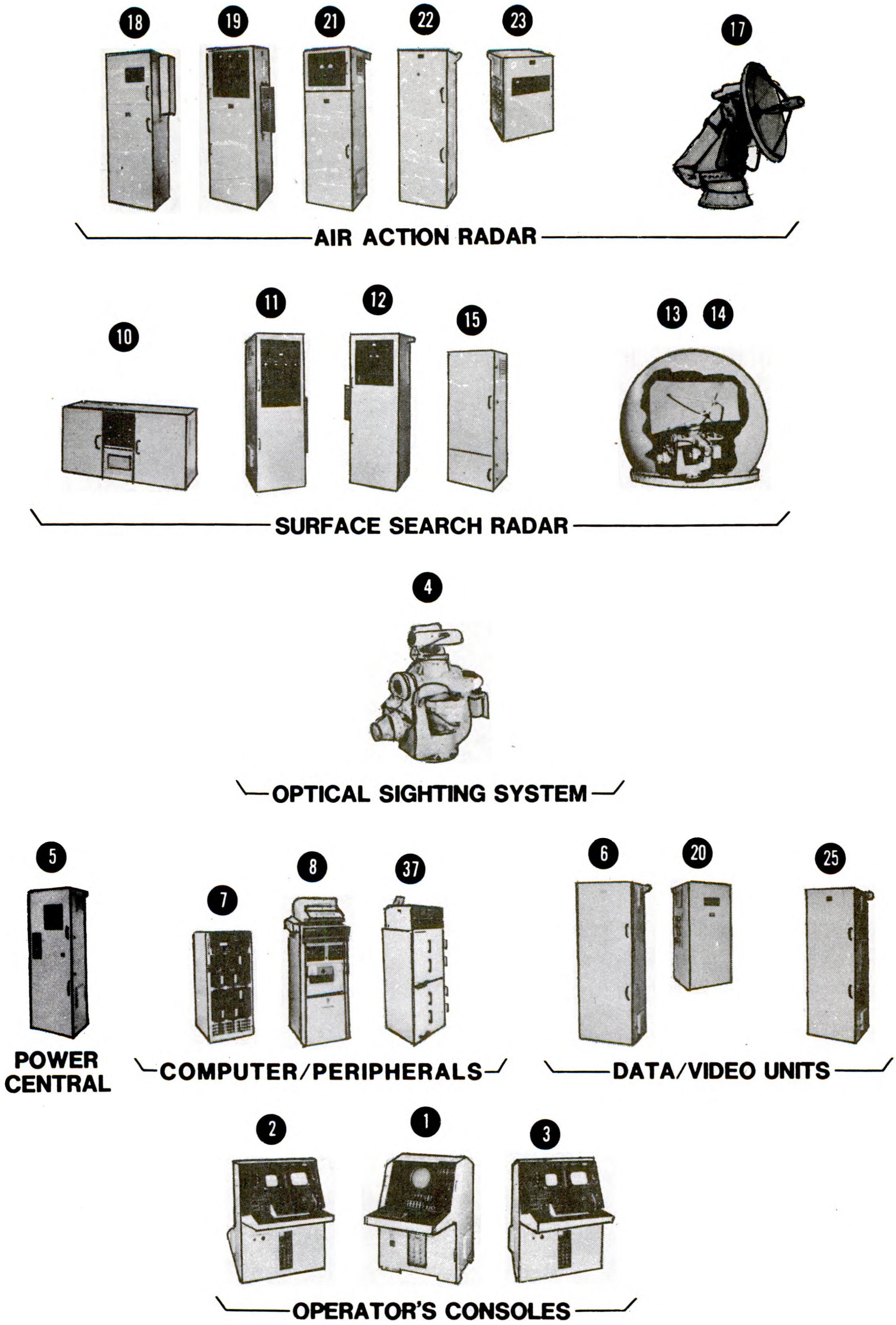

Figure 9-10.—Mk 86 Mod 10 FCS.

of discussion, the physical units are grouped into related functions as follows:

1. Operator consoles
2. Power central
3. Computer/peripherals
4. Surface search radar
5. Air action radar
6. Data/video units
7. Optical sighting system

Operator Consoles

The operator consoles consist of the Control Officer Console Mk 67 (COC, Unit 1) and two Mk 113 weapons Control Consoles (WCC1 and WCC2, Units 2 & 3). The COC and WCCs are the principal command positions for the Mk 86 FCS.

The COC allows the control officer to control and monitor overall operation of the FCS. From this position he initiates radar tracking of targets and assigns weapons to the WCCs.

An operator may control one or both guns from either WCC, depending on the weapon assignment made by the COC operator. The WCC operator enters fire control data into the computer through his keyboard and associated controls. This data includes ballistics data, ammunition selection, target data, grid coordinates, and spotting data. The WCC also has a TV monitor for visual surveillance and optical tracking.

Power Central

Power central (Mk 12, Unit 5) is the central power control and distribution point for all units except the AN/SPG-60 radar set, the digital computer, and the digital I/O console.

Computer/Peripherals

The systems computer/peripherals group consists of the AN/UYK-7 computer, the digital input/output (I/O) console, and the magnetic tape recorder-reproducer. (These units are shown as Units 7, 8, and 37 respectively in figure 9-10.)

DIGITAL COMPUTER AN/UYK-7.—The FCS uses the AN/UYK-7 general-purpose computer set. The program, once loaded into the computer memory, contains all instructions and constant data required to perform the computations and functions related to the fire control problem. The computer performs ballistic computations to determine the gun line-of-fire and projectile time-of-flight from which gun orders are generated.

DIGITAL I/O CONSOLE.—The digital input/output (I/O) console consists of a paper tape reader and perforator, and a teletypewriter (keyboard/printer). The I/O console is primarily used for troubleshooting and for running system diagnostics.

MAGNETIC TAPE RECORDER-REPRODUCER (MTRR).—The magnetic tape recorder-reproducer interfaces with the AN/UYK-7 computer to load the operational and maintenance programs for the system. The MTRR also records all system engagements for future review.

Surface Search Radar

The surface search radar consists of Radar Set AN/SPQ-9A, which is comprised of Units 10 through 15 (fig. 9-10).

Unit 10—Radar receiver

Unit 11—Frequency converter

Unit 12—Transmitter

Unit 13—Antenna

Unit 14—Radome

Unit 15—Control amplifier

The AN/SPQ-9A is the prime sensor of surface targets for the Mk 86 FCS. The radar is also equipped with circuitry for the reception and interrogation of a radar beacon (described in the next chapter).

Air Action Radar

The air action radar consists of Radar Set AN/SPG-60, the system's tracking radar, which provides the director/radar inputs to the computer. The system is comprised of Units 17 through 19, and 21 through 23 (fig. 9-10).

Unit 17—Antenna

Unit 18—Radar Receiver

Unit 19—Radar Transmitter

Unit 21—Antenna Control

Unit 22—Signal Data Converter

Unit 23—Power Distribution Control

The antenna is mounted with a TV sight that allows the WCC operator to visually track targets. The same antenna is used in variations that supply CWI with the addition of a waveguide and feedhorn for CWI transmission.

Data/Video Units

The data/video units consist of a Signal Data Translator (Unit 6), Signal Data Converter (Unit 20), and a Video Processor (Unit 25). The signal data translator interfaces the computer with other units of the Mk 86 FCS. The signal data converter converts gun position synchro signals for use by the signal data translator. The video processor operates in conjunction with the computer system to acquire, track, and develop position and rate data for targets detected by the AN/SPQ-9A Radar Set. The video processor receives raw data from the radar, and correlates it with present and previous radar echoes to provide a high detection probability and low incidence of false alarms.

Optical Sighting System

The optical sighting system (Unit 4) consists of a gimbal-mounted TV camera (separate from the one mounted to the AN/SPG-60 antenna). The sight permits the WCC operator to monitor and track targets visually. The sight can be positioned automatically by the computer or manually by the WCC operator.

MK 92 FCS

The Mk 92 FCS is installed primarily on FFG-7 class ships. The system, in conjunction with the Mk 13 Mod 4 GMLS and the 76-mm Mk 75 gun, is capable of simultaneously detecting, tracking, and engaging multiple air and surface targets. Much of the terminology, and some of the components, associated with the Mk 92 FCS are similar, or identical, to those used in the Mk 86 FCS. Both systems, for instance, use the AN/UYK-7 general-purpose computer set to perform all the fire control calculations. Watch for other similarities as we describe the functions of this system's major components. The system consists of the following major components:

1. Combination Antenna System (CAS) and radar
2. Separate Track and Illuminating Radar (STIR)
3. Weapon Control Processor (WCP)
4. Data Exchange Auxiliary Console (DEAC)
5. Planned Position Indicator (PPI) Display Console

Combined Antenna System (CAS)

The Combined Antenna System (CAS) consists of search and track antennas mounted on a stabilized platform and enclosed in a radome (fig. 9-11). The search antenna provides air and surface surveillance, but can also be used to track a limited number of targets while scanning. The search antenna is also equipped with IFF for target interrogation.

The CAS track antenna is primarily used for three-dimensional (3-coordinate) tracking of air targets. The antenna is also equipped with a continuous wave illumination (CWI) horn to provide target illumination for the guidance of Standard semiactive missiles.

Both antennas are part of the same radar unit. Both are controlled and operated from the CAS Weapon Control Console (WCC). The CAS WCC is a two-operator console. One operator is responsible for the acquisition, tracking, and engagement of air targets by gun or missile. The second operator is responsible for the tracking and engagement of surface targets. The console is interfaced with the WCP. In the normal mode of operation, the WCP designates targets for engagement by the CAS operators.

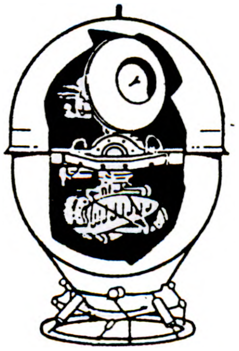

Figure 9-11.—The combination antenna.

Separate Track and Illuminating Radar (STIR)

The Separate Track and Illuminating Radar (STIR) (fig. 9-12) provides the system with a longer range tracking capability than is possible with CAS. STIR is solely a tracking radar with no search capability. The antenna is equipped with CWI for the control of Standard missiles. STIR is a separate radar from CAS.

The STIR WCC is a single operator console. It is identical to the CAS WCC except that the search radar controls have been eliminated. The operator is responsible for the acquisition, tracking, and engagement of targets by gun or missile, as ordered by the WCP.

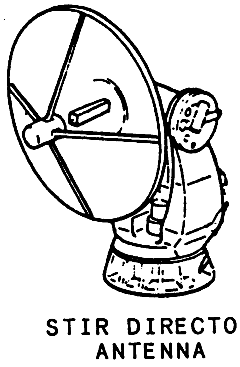

Figure 9-12.—The STIR director antenna.

Weapons Control Processor (WCP)

The Mk 92 FCS uses the AN/UYK-7 computer set to perform all fire control calculations and threat evaluations. The WCP is the source of gun mount and missile launcher position orders and missile programming.

Data Exchange Auxiliary Console (DEAC)

The Data Exchange Auxiliary Console (DEAC) provides a variety of input and output capabilities for the WCP. The DEAC provides a keyboard and page printer, a paper tape reader and punch, a magnetic tape recorder/reproducer, and an output teletype communications interface. The DEAC is capable of accepting from either the WCP or the weapon support processor (WSP) (the WSP is another AN/UYK-7 computer that is part of the WDS). The DEAC can exchange data with either the WCP or the WSP.

Planned Position Indicator (PPI) Display Console

The Planned Position Indicator (PPI) console, an AN/UYA-4, serves as the Weapons Control Officer (WCO) console. It displays selected radar and track data received from external search radars and the CAS search radar. The console may also be used, in the casualty mode, to enter track data into the WCP.

Figure 9-13 illustrates the equipment layout aboard an FFG-7 class ship.

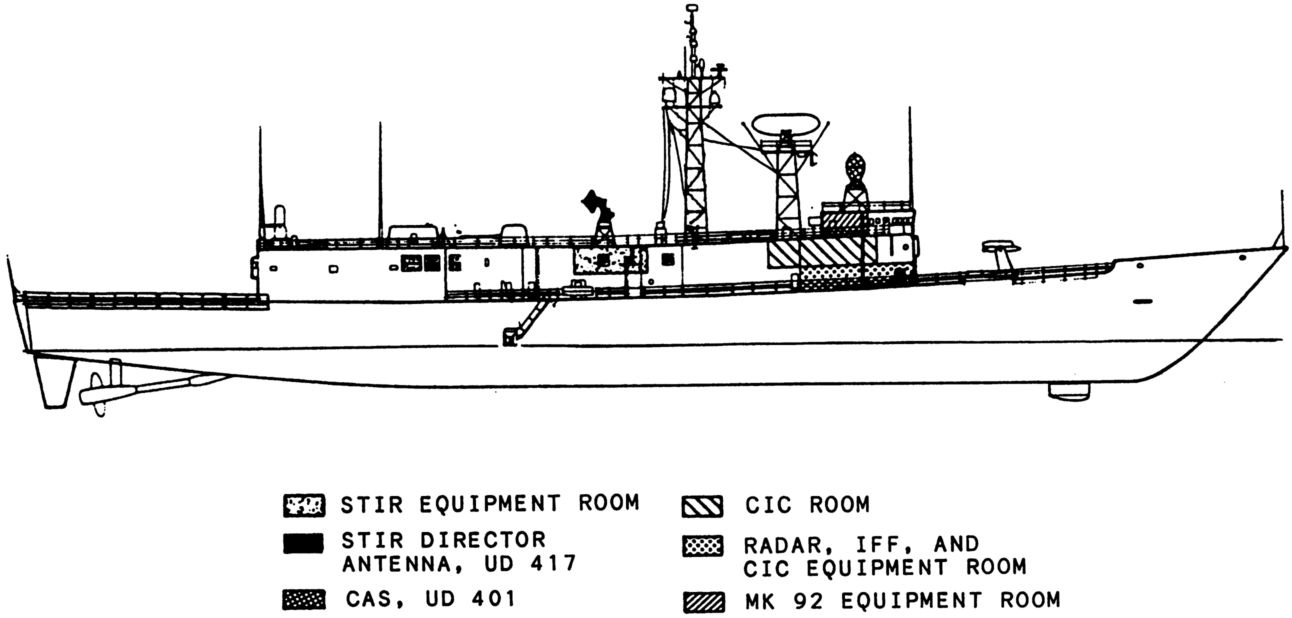
▨ STIR EQUIPMENT ROOM
■ STIR DIRECTOR ANTENNA, UD 417
▩ CAS, UD 401
▧ CIC ROOM
▦ RADAR, IFF, AND CIC EQUIPMENT ROOM
▨ MK 92 EQUIPMENT ROOM

Figure 9-13.—Mk 92 FCS equipment configuration on FFG-7 class ships.

SUMMARY

In this chapter we have covered the fundamental elements of a control system. We have described the function of WDS as an information gatherer and engagement controller. We also described the elements of a fire control system, and how they receive target data from the WDS and use it to engage the target. Next, we examined some of the compensations in the fire control problem required to deliver accurate fire. Finally, in the last section, we covered the three most modern fire control systems currently in the fleet. This chapter should round out your perception of a modern weapon system aboard a surface vessel. In later chapters, we will describe some of the other specialty areas in the weapons world.

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Maintenance Manual for Fire Control System Mk 92 Mod 2, Description, Operation, and Maintenance (U), SW271-C2-MMO-010/(C) Mk 92 Mod 2, Vol. 1 Part 1, Naval Sea Systems Command, Washington, D.C., 1987.

CHAPTER 10

SPOTTING AND NAVAL GUNFIRE SUPPORT

In this chapter we continue discussing the problem of gunfire control where we left off in chapter 9. Here, we discuss certain advanced aspects of fire control in the special situation where naval guns are used against targets ashore, particularly in connection with amphibious attacks.

Gunnery operations, rather than principles of weapons and associated equipment, are the subject of this chapter. In studying them, bear in mind that operational methods and techniques are broadly determined by the Chief of Naval Operations and other responsible command echelons. They are published as doctrine in NWPs and other related publications. The following material is NOT intended to take the place of this doctrinal information.

In chapter 9 we discussed the factors that affect the flight of a projectile, how these factors are anticipated, and how flight corrections are handled. However, even with the best fire control equipment available, experienced gun crews, and efficient fire control personnel, the opening shots may not hit the target. It is therefore necessary to apply corrections (spots) to the initial firing data to bring the shots on the target. The corrections are applied to gunlaying data for subsequent rounds fired. This technique is called spotting.

SPOTTING TERMINOLOGY

Before proceeding further, we will define some terms that relate to gunfire support and spotting. Those terms are as follows:

SLOW FIRE. In slow fire, firing is deliberately delayed to allow for application of spots or conservation of ammunition.

RAPID FIRE. In rapid fire, firing is NOT delayed to apply corrections.

SALVO. A salvo consists of one or more shots fired simultaneously by the same battery at the same target.

SLOW SALVO FIRE. In slow salvo fire, the guns are loaded on command and fired together at a fairly SLOW rate.

RAPID SALVO FIRE. In rapid salvo fire, the guns are loaded on command and fired together at a RAPID rate. (Both slow and rapid salvo fire are used to establish a hitting range to a surface or land target.)

RAPID CONTINUOUS FIRE. Rapid continuous fire is the fastest firing method for guns. In the case of the 5"/38 and 3"/50 guns, the pointer's firing key is held in the closed position, and the rate of fire depends only on the loading speed of the crew. Guns with automatic loading systems are simply given a firing order. The pressing of a button engages the loading system while a firing circuit is supplied. As each round is fired and its empty case expelled, another is loaded behind it until the system is empty or the ceasefire command is given. The loading system is governed to operate at a certain speed, which translates to a rate of fire.

RAPID PARTIAL SALVO FIRE. Rapid partial salvo fire for a turret is synonymous with rapid continuous fire for a 5" gun. (Both of these types of fire will most often be used after the hitting range has been established, or in the case of the 5" gun, against aircraft.)

MEAN POINT OF IMPACT (MPI). The Mean Point of Impact (MPI) is the geometric center of the points of impact of the various shots of a salvo, excluding wild shots (fig. 10-1, view B).

DISPERSION. The dispersion of a shot is the distance of the point of impact of that shot from the MPI.

APPARENT MEAN DISPERSION. The apparent mean dispersion of a salvo in range (or deflection) is the arithmetical average of the dispersion in range (or deflection) of the several shots of the salvo, excluding wild shots.

TRUE MEAN DISPERSION. The true mean dispersion is the arithmetical mean of the dispersions in range (or deflection) of an infinite number of shots, all assumed to have been fired under conditions as nearly the same as possible.

WILD SHOT. A wild shot is a shot with an abnormally large dispersion in range, deflection, or both.

PATTERN. The pattern of a salvo is the area covered by the points of impact of the shots (except wild shots). The pattern in range is the distance measured parallel to the line of fire between the point of impact closest to the battery and the one farthest away, excluding wild shots. The pattern in deflection is the distance, measured at right angles to the line of fire, between the point of impact farthest to the right and the one farthest to the left, excluding wild shots.

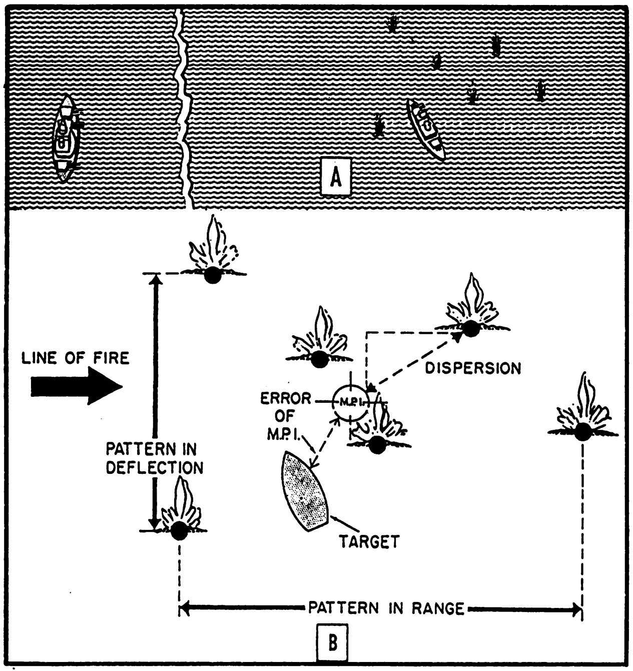

Figure 10-1.—Salvo pattern.

HITTING SPACE. Hitting space (usually measured only in range) for a target is the distance behind the target (measured parallel to the line of fire) that a shot through the top of the target will strike the horizontal plane through the base of the target (fig. 10-2). Hitting space includes the projection of the target's vertical height upon the plane of the water and the target's horizontal dimension in the line of fire (or depth). Hitting space in deflection is the angle subtended by the target.

DANGER SPACE. The danger space for a target is the distance in front of the target, measured parallel to the line of fire, that the target could be moved toward the firing point, so that a shot striking the base of the target in its original position would strike the top of the target in its new position (fig. 10-2). At most ranges, danger space is virtually equal to hitting space.

STRADDLE. A straddle is obtained from a salvo in range (or deflection) when, excluding wild shots, some of the shots of that salvo fall beyond and some shots fall short of the target (or right and left, respectively, for deflection). The target in figure 10-1, view A, is straddled.

ERROR OF MPI. The error of the MPI is its distance from the target (fig. 10-1, view B) or other reference point such as the center of the hitting space, measured (in a horizontal plane) parallel to the line of fire for range and at right angles to the line of fire for deflection.

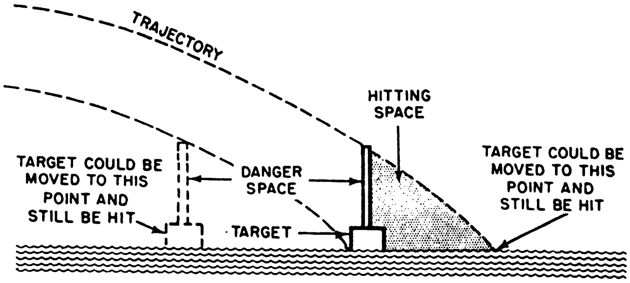
TRAJECTORY
HITTING SPACE
TARGET COULD BE MOVED TO THIS POINT AND STILL BE HIT
DANGER SPACE
TARGET
TARGET COULD BE MOVED TO THIS POINT AND STILL BE HIT

Figure 10-2.—Hitting space and danger space in range.

ELEMENTS OF SPOTTING

Now that you are familiar with some of the terms relating to spotting and gunfire support, we will discuss some of the problems encountered in these areas.

DISPERSION

The problem of spotting is complicated by dispersion. If a battery of guns is fired at the same instant with the same settings in range and deflection (this is salvo fire), the projectiles will not all land at the same point, but will be dispersed over the vicinity.

If the battery of guns were stationary and rigidly fixed in elevation and train, variations in range and deflection could be caused by (1) differences in weight and temperature among individual powder charges; (2) differences in projectile weights; (3) variations in angles of projection (the longitudinal axes of projectiles diverge, in varying amounts, from the continuation of the bore axis as they leave the guns); (4) differences in projectile seating, causing variations in density of loading and initial velocity; and (5) differences in erosion among the several guns, with corrections not precisely made. Each of these differences will make a certain minimum amount of dispersion inevitable.

There are other causes of dispersion, however, which can be prevented or minimalized by adequate training. The motion of the ship may result in the guns being off target when they are fired locally (without the use of the fire control system). The same effect may result from failure to fire exactly simultaneously, causing different guns to fire at slightly different points in the roll.

Computer-controlled gunfire, although not subject to the same characteristic errors as locally controlled fire, is subject to its own characteristic errors. All such errors are considered accidental errors. They are revealed by analyses of firings, and their effects are governed by the laws of probability.

As range increases, hitting space decreases, and as dispersion increases, the probability of hitting decreases. The error of the MPI, with respect to the target, depends on the state of training, the material conditions of the firing ship, the accuracy of the charts, and the firing range. An officer detailed to duties that include spotting, should know the dispersion and pattern at various ranges up to the maximum range of his battery. These factors must be considered when determining the safety limitations of initial salvos.

Since dispersion of individual shots is caused by unpredictable errors, it is logical to assume that no two salvos will be exactly alike. Therefore, the MPI of the shots of a given salvo can be expected to differ in location from the MPIs of other salvos.

The average shift between successive MPIs is usually so small as to be difficult for the spotter to estimate. For this reason, the spotter should not be too quick to spot when only one or two salvos seem to wander off the target during a string that is, in general, satisfactory.

CONTROL ERRORS

The only accidental errors discussed thus far have been those that affect individual guns of a battery in local control. These are known as gun errors, and should be distinguished from another class of accidental error that affects the battery as a whole. These are known as control errors and include errors in computing, in transmitting of data to the guns, in director fire, and director pointing errors. They are not reflected in increased pattern sizes (i.e., increased dispersion among the guns), but are characterized by increased dispersion or error of the MPIs themselves.

There are four general control inaccuracies that may cause MPI error. These are listed in the order of highest probable frequency of occurrence and magnitude of effect:

1. Computer set up with incorrect values
2. Ballistic corrections based on incorrect values
3. Battery not properly aligned with director
4. Indeterminate errors

Let us now consider each of these sources of control errors.

Incorrect Computer Setup

Determination of target course and speed is made directly from the spotter's estimate of target angle and speed, from CIC, or by rate controlling. Correct values of these two variables are difficult to determine. They are the chief cause of incorrect computer setup, and therefore, the chief source of MPI error.

Present range to target is valid only so far as its measurement is accurate. An error in basic range measurement directly causes an error in MPI.

Measurement of own-ship course and speed usually is reasonably accurate, but any inaccuracies result in an error in MPI.

Inaccurate Ballistic Corrections

The computer determines the corrections for variations from standard conditions. Determination of these corrections, based on incorrect values of ballistic wind, I.V., wind, air density, etc., will give a total ballistic correction that will result in a corresponding error in MPI.

Poor Battery Alignment

Improper alignment between the guns of a battery results in greater dispersion and larger pattern sizes, but does not materially affect the error of the MPI of a salvo. In contrast, MPI error can be caused by misalignment between the controlling director and the battery as a whole. Such misalignment is generally caused by failure to director-check the battery and all directors. A battery aligned with one director is not necessarily aligned with another that may be in control. Frequent director checks can assist in elimination of this cause of MPI error.

Indeterminate Errors

There are two classes of indeterminate errors. Some of the computations made by mechanical computing elements in fire control instruments are only approximations of the true solutions. These approximations result in errors that are small for normal ranges and therefore cause minimum error in MPI. However, at extremely short or long ranges, the errors may become large, depending on the instrument concerned, and may seriously affect the MPI. When these errors are known to be large, they can no longer be treated as accidental, and steps must be taken to make correction for them.

The other class of indeterminate errors is assignable to control personnel. The director pointer, trainer, or OMC operator may be off the point of aim when the salvo is fired. Training and experience can reduce the magnitude of such mischance. Small errors of this type merely cause a slight shift of MPI and should not be corrected by the spotter. The director operator should inform the spotter of larger discrepancies in the point of aim, so that the spotter may distinguish this error from others.

It is not enough for the spotter to detect errors, estimate the spots required, and transmit them. He must be able to recognize the causes of errors by understanding their characteristics and knowing what to expect of the batteries he is working with, and then make up his spots with this information in mind.

FUNCTIONS AND DUTIES OF THE SPOTTER

The primary function of the spotter is the correction of range and deflection errors of the MPI to bring the shots on the target. Prompt and accurate correction of initial errors may be the deciding factor in a naval engagement. The spotter bases these corrections on his own observations, combined with those of the fire control radar operator. As a rule, in good visibility, the spotter will estimate the necessary deflection correction, and range corrections will be obtained from the radar. Under unfavorable conditions, both range and deflection corrections will be obtained from the radar. If radar fails, optical spotting must substitute.

In our initial discussion of the spotter's problems, let us assume that radar is not available.

Besides his primary function of correcting the fall of shot, there are other functions which the spotter must perform before and during firing. In general these are described in the following statements:

1. Describe the enemy forces (general bearing line, number of ships, deployment, etc.).
2. If he is also acting as the control officer, estimate the values of range, target angle, and target speed, and keep plot informed of all changes to these values.
3. Keep control informed of the tactical situation.

There are other functions the spotter may be required to perform, the nature of which will vary with different types of ships. The spotter's detailed functions and spotting procedures are prescribed in the appropriate NWPs for each class of ship and in fleet doctrinal publications.

VISUAL ESTIMATE OF TARGET COURSE AND SPEED

To arrive at a solution of the fire control problem, the computer must have target course and speed. Often the spotter can obtain this data by observation through binoculars.

To determine target course, the spotter must be able to accurately estimate target angle (relative bearing of own ship as seen from the target). To estimate target angle, the spotter must know the structural details of all likely targets. Silhouettes of all probable targets are furnished each ship. The spotter should study the details of these visual aids, not only for the purpose of recognizing the enemy, but also for estimating target angle. In estimating target angle, the spotter should make use of prominent objects such as bridges, breaks in the deck, stacks, masts, and other features. By observing the opening and closing of the apparent distance between such details, the spotter can estimate the angle the enemy ship makes with the line of sight.

Target speed can at best be only roughly estimated. Here again, knowledge of enemy ships is invaluable, particularly regarding maximum speeds. Target speed may be estimated as about 1 or 2 knots less than the maximum speed of the slowest ship in the formation.

To make the best speed estimates, the spotter must have extensive training and experience. Some of the aids used by a spotter in a direct estimation of target speed are smoke from the stacks, bow wave, and stern wake. A spotter who knows his target size can also make accurate preliminary estimates of range by using the mil graduations in his binoculars. (Mils are discussed in the following section.)

SPOTTING IN DEFLECTION

Because it is simpler to make range spots when there is no deflection error (particularly at long ranges), the spotter customarily calls deflection spots first. The unit used in deflection spotting is the angular mil.

The Mil and Its Use

You may already be acquainted with the angular mil because it is the unit in which gunsight deflection scales are calibrated. There are about 6400 mils to a circle, and 1 mil is about .056°, or 3.37 minutes of arc. The reason for using the mil as an angular unit in measuring deflection, rather than using degrees or minutes, is that it has a very useful property. If a distant object appears to an observer to have an angular width of 1 mil, then the actual width of the object is 1/1000th of the range.

Telescopes, binoculars, and other optical devices for naval use often have reticles (a network of fine lines) with mil scales etched on them. If you use such binoculars to look at, say, a 30-foot boat broadside, at a range of 1000 yards, the image you see in the binoculars will have an angular width of 10 mils. Figure 10-3 shows further graphical examples of the relationship between mils and range. Part A of the figure shows how 1 mil subtends different linear distances at different ranges, and part B shows several other examples of the relationship. To bring the use of mils down from this theoretical

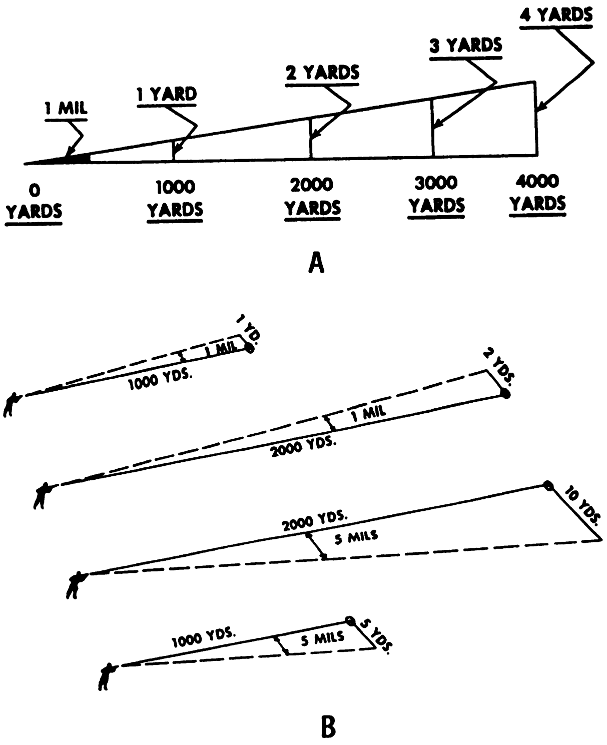

Figure 10-3.—The angular mil and how it is used.

level, look at figure 10-4. What is the linear size in deflection of salvo A's pattern?

Salvo A at a range of about 11,500 yards subtends 5 mils. One 1/1000 of the range is 11.5 yards; multiplying by 5 (mils) gives an actual pattern width in deflection of 57.5 yards. As a practical matter, of course, it's absurd to specify a pattern width down to a half yard; rounding off, the answer would be about 58 yards.

In estimating deflection spots, use target width in mils as a guide.

Allowing for Splashes

With a high-speed surface target, the spotter should bear in mind that the apparent MPI in defection should be held abaft the point of aim to allow for target travel while the splashes are forming. Do not assume that full splashes form instantaneously at the impact of a salvo. The time lag is only a few seconds at most, but is sufficient to allow considerable movement of faster targets.

SPOTTING IN RANGE

Spotting in range is more difficult than spotting in deflection. There is no convenient angular measure that is uniformly applicable at all ranges, like the almost foolproof mil.

Figure 10-4 is adapted from a typical spotting diagram. It is a graphic presentation of how different ranges look to you as an observer 100 feet above the surface of the water. The lateral broken lines represent ranges in increments of 1000 yards; the diagonal broken lines represent angular mils; and the curved solid line at the right shows the apparent length in mils of a 600-foot broadside target at various ranges. Unfortunately, the natural seascape is not marked with these handy reference lines, but the diagram is a helpful guide in learning how to estimate ranges. It is used in conjunction with such training aids as miniature spotting boards, and with observation during target practice.

The range lines in figure 10-4 represent the angular distance below the horizon at which any object would appear from a height of 100 feet, if observed on the corresponding range lines. The

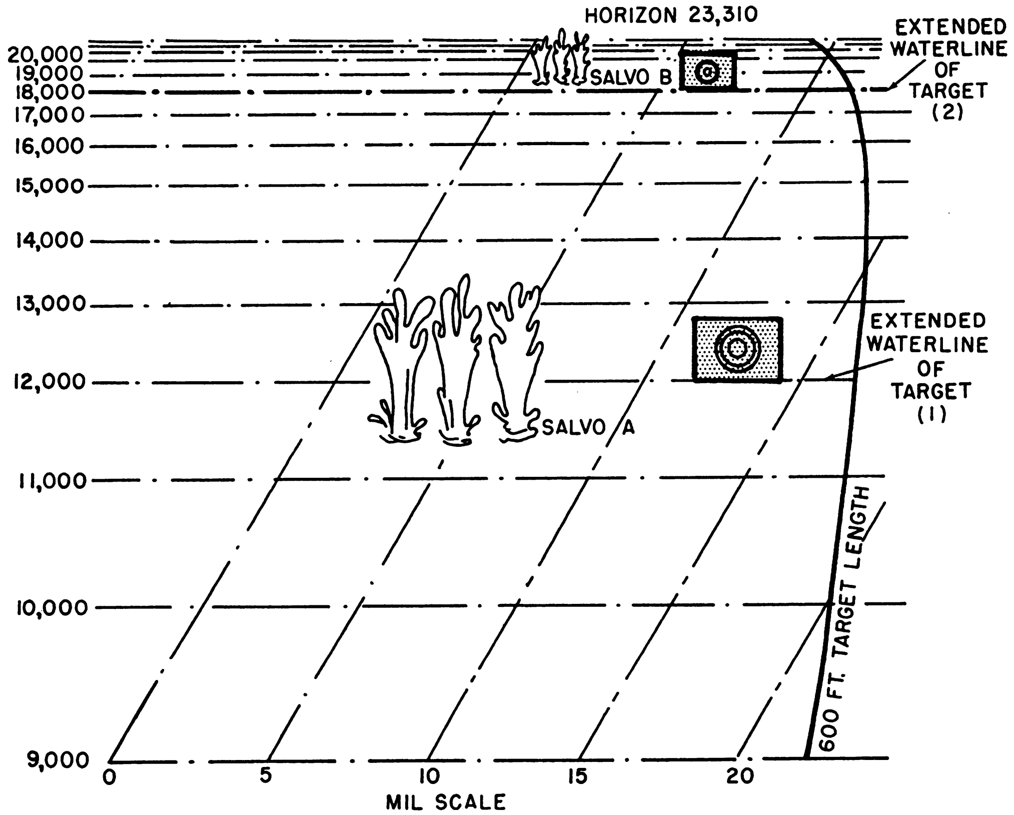

Figure 10-4.—Practice diagram for range spotting.

distances between the range lines represent the apparent range differences as viewed by an observer at the height for which the diagram was constructed (in this case, 100 feet).

A study of figure 10-4 shows that salvo A is clearly short, by about 500 yards, of the imaginary extension of the waterline of a target at 12,000 yards. However, the error of salvo B, fired at a target at 19,000 yards, is not so apparent. The 500-yard error of salvo B, is difficult to see when compared with the extended waterline of the target. Thus, for shipboard spotting at such a range, the splashes must be in line with some portion of the target before the spotter can reasonably tell whether the salvo is over or short, to say nothing of estimating the amount of the error.

In addition to its use for estimating range and range errors, the spotting diagram shows the number of mils a given target length will subtend at any given range. For example, in figure 10-4, a 600-foot target will subtend 20 mils at 10,000 yards range.

One of the most common mistakes made by the untrained spotter is to underestimate the amount of range error at long ranges. This is because a given range error will subtend a much smaller angle at long ranges than it does at short ranges. However, with good visibility, and from a height of 120 feet or more, the MPI error can usually be estimated with reasonable accuracy at ranges up to 15,000 yards. This is accomplished by observing the position of the bases or slicks of the splashes relative to the target waterline.

METHODS OF SPOTTING

This section is primarily concerned with methods of visual spotting and spotting with radar. Before discussing these methods, however, we will present some of the terminology used in spotting.

SPOTTING TERMINOLOGY AND MESSAGE PRACTICE

As in other operational communications, there is a prescribed terminology and message sequence for spotting. These are published in fleet operational directives. The examples that follow show the general practice at this time.

Surface Fire

For surface fire, only range and deflection are spotted. The correction necessary to bring the MPI on target is given in the following terminology sequence.

1. Deflection correction—RIGHT or LEFT (in mils).
2. Range correction—ADD or DROP (in yards).

When no correction in deflection is necessary, only a range spot is made. When no range spot is necessary (regardless of whether a deflection spot is required), the phrase NO CHANGE is used. Typical examples of spot transmissions by telephone are RIGHT 10, ADD 1,000; LEFT 5, DROP 500; LEFT 10, NO CHANGE; NO CHANGE, NO CHANGE.

AA Fire

For air targets, corrections to bring the burst on the target are needed in three dimensions. Even well-trained personnel find it almost impossible to estimate errors rapidly in three dimensions. AA spotting, therefore, is generally limited to correcting for obvious constant system errors.

The proper terminology for spotting in AA fire is as follows:

1. Deflection correction—RIGHT or LEFT (in mils)
2. Range correction—ADD or DROP (in yards)
3. Height-of-burst correction—UP or DOWN (in mils)

Deflection and elevation spots will normally be made by the control officer. Range spots will be made by the range finder or radar operator.

NOTE: Spotting should not be attempted while shooting but only after a run is completed.

Naval Gunfire Support

In shore bombardment, as in AA fire, spots in three dimensions may be necessary. The terms are the same as in the preceding paragraph, but the units are not the same. When naval guns are used to support landing operations, joint forces are involved. The Navy, Army, Air Force, and NATO have a standardized spotting terminology for joint operations that will differ from the terminology already discussed. All corrections for indirect fire are spotted in meters. Most fire control equipment, however, is calibrated in yards. Therefore, meters must be converted to yards and mils for input into the fire control computer.

Corrections in three dimensions are made in the following order:

1. Deviation (Deflection)—RIGHT OR LEFT
2. Range—ADD or DROP
3. Height of burst (HOB)—UP or DOWN

Naval gunfire support will be discussed in greater detail later in this chapter.

VISUAL SPOTTING METHODS AND TECHNIQUES

There are three methods of visual spotting:

1. The direct method
2. The bracket-and-halving method
3. The ladder method

The method used depends upon the type of battery firing, type of target, visibility, and range.

Direct Method

Spotting by the direct method is, as its name implies, the spotting of salvos (splashes) direct to the target. This is the most desirable procedure, but its use is limited to short ranges and good visibility conditions. For reasonably accurate visual spotting at a range of 15,000 yards, a spotting height of 120 feet is required. The splash must be relatively close to the target, and the rangekeeper (or computer) set up fairly accurate.

A thoughtful analysis of the problem with reference to the spotting diagram in figure 10-4 reveals that the greatest limitation of the direct method in visual spotting is in range. Deflection spots can be made with equal accuracy at any visible distance. If air observation is available, and the plane spots in range with the ship spotting in deflection, the direct method can be used by the battery at any range at which a portion of the splash is visible to the shipboard spotter. Air spotters cannot accurately spot in deflection unless they have a line of sight containing the firing ship and the target. Spotting the fall of shot at very short ranges differs from other spotting problems in that range errors are not difficult to judge. However, in determining deflection errors at short ranges, consideration must be given to the travel of the target and the spotter's position relative to the line of projectile flight. For example, with the firing ship and target on opposite courses, target to starboard, a shotfired with correct deflection, but long in range, will appear to the spotter to be in error to the left of the target. Special short-range splash diagrams aid the spotter in this type of firing.

Bracket-and-Halving Method

Bracket-and-halving is used at long ranges when no air or radar spot is available, and the range is estimated. At great distances it is impossible to tell if a splash is short of, or over a target, unless the two are in line. If the splash and target are not in line, the first spot is made in deflection only. When the target and splashes are in line in deflection, a range spot is made in such a direction and amount as to "cross" the target definitely. The direction of the next spot is reversed, and the size of the spot is cut in half. This "halving" is continued until a straddle is obtained, at which time it may be appropriate to shift to rapid partial salvo or to rapid continuous fire. The spot should not be reduced below pattern size.

Ladder Method

When ranging is difficult and visibility poor because of fog, smoke, or darkness, the ladder technique is valuable. Ladders are not particularly adaptable to fast-moving targets. There are many variations of this technique, but the basic procedure is as follows:

1. Fire is deliberately opened short.
2. Succeeding salvos are fired to approach the target in steps not less than pattern size.
3. As soon as the target is crossed, the steps are reversed and halved until the target has again been crossed. After the target is straddled, a rocking ladder may be used with slow timed fire, or with rapid partial salvo or continuous fire. In a rocking ladder the pattern is shifted back and forth across the target by small arbitrary successive spots, such as +100, 0, −100, . . . , introduced at the computer. Its effect is to increase the pattern size, which may be valuable when firing against a target capable of rapid maneuvering. The rocking ladder can be used in conjunction with air or radar spotting, as long as the spotter is kept informed that this technique is being used.

SPOTTING WITH RADAR

Radar spotting has proved to be both accurate and reliable within the range of surface batteries. Radar provides a means of spotting that is independent of conditions of visibility, so that blind spotting is possible with blind firing.

Shell splashes appear on the scope as fluctuating echoes, which last for several seconds depending upon the size of the projectile and the range. The large column of water thrown up by the projectile produces the echo. Salvos produce larger or multiple echoes on the scope.

If the projectile stays within the vertical limits of the radar beam, its flight to the point of impact can be followed on the scope on main sweep. The projectile produces a small, weak, moving echo, which begins at the edge of the scope and moves out in range toward the target. At the point of impact, the echo stops and grows larger as the splash builds up. Echoes from direct hits or near misses will be lost in the target echo, while salvos that straddle the target may envelop the target echo in the midst of the splash echoes on the scope, thereby making it impossible to distinguish individual splashes. Range errors can usually be estimated by radar with greater accuracy than by optical spotting, but deflection spotting with radar is difficult, especially when the error is small. Near misses sometimes merge with, and are indistinguishable from, the target pip. Target practice is used to determine the minimum deflection error that can be detected on a particular radar. When radar is the only means available for deflection spotting, the deflection "rocking ladder" should be used. The order of preference in spotting surface fire is usually: RANGE-radar, air and visual; DEFLECTION-visual, radar, and air. In night action, or action under reduced visibility, radar normally spots for both range and deflection.

SPOT PYRAMIDING

The application of a new spot before the effect of a previous spot has had time to become apparent is called spot pyramiding. It can occur only in rapid fire when the interval between shots or salvos is less than the time of flight plus the spotting interval. In that case, when a salvo lands, there are one or more other salvos in the air. Suppose the spotter makes a spot on the salvo that has just landed. The spot is applied and a new salvo is fired. Then, one or more of the salvos that were already in the air lands, and the spotter, forgetting that his previous spot has not had time to show its effects, spots again. The spot is applied to the next salvo fired, with the result that this salvo is overcorrected and will probably miss, as will subsequent salvos until the spotter sees his mistake and spots back again.

The time of flight clock signal helps to avoid pyramiding. A button on a mechanical time clock is pressed in the plotting room when the salvo on which a spot is applied is fired. The clock has been preset to ring just before the time of flight of the projectile ends. Before the salvo lands, the mechanism sounds a buzzer. This is then relayed to the spotter via sound-powered phones.

Because spot pyramiding is common and has a disastrous effect on accurate control of fire, the means used to prevent it must be carefully and correctly operated. For example, if the time-of-flight mechanism operator forgets to press the button for a spotted salvo, and the spotter waits for the signal, he may continue to wait after it becomes apparent that his previous spot was incorrect. Also, when modern fire control systems are being used to solve the fire control problem, as described in chapter 9, the system is automatically making constant corrections to the solution. If spots are applied at the same time as these corrections, the effect is the same as the pyramiding of spots. Under normal circumstances, AA fire is computer controlled. Therefore, the spotting of air bursts is rare.

FUNDAMENTALS OF NAVAL GUNFIRE SUPPORT

In World War II, naval task forces frequently carried out bombardments of enemy installations on shore. After the ineffective results noted during the Tarawa operation in November 1943, shore bombardment techniques were gradually improved through successive landings at Roi-Namur, Eniwetok, Saipan, Guam, Peleliu, the Philippines, Iwo Jima, and Okinawa. Later, the Korean War and the Vietnam conflict gave frequent opportunities for the refinement of the techniques learned in World War II.

An opposed amphibious landing is one of the most hazardous types of military operations. Until World War II, many military authorities believed that such an operation was too hazardous to be attempted. In part, this belief was based on the Allied failure in the amphibious Dardanelles (Gallipoli) campaign during World War I. Analyses attribute the failure, at least partially, to inadequate naval preparation before the campaign.

To be successful, naval gunfire support (NGFS) for amphibious operations must be carefully planned in advance, and must be executed with skill and dispatch. It is vitally important in the period after the troops have landed, but before adequate artillery can be brought into action. Its full exploitation can be achieved only if ground, naval, and air personnel understand the organization, basic techniques, capabilities, and limitations of naval gunfire support, and follow the standard procedure that has been agreed upon by the joint services and NATO. *Allied Spotting Procedures For Naval Gunfire Support*, ATP-4, and *Supporting Arms in Amphibious Operations*, NWP 22-2, are two foundational documents that should be read gain a clear understanding of NGFS fundamentals.

PURPOSE OF SHORE BOMBARDMENT AND NAVAL GUNFIRE SUPPORT

Naval gunfire is delivered from ships' batteries not only in support of troop operations, but also to support related naval and air operations. These operations include mine warfare activities, air-sea rescue operations, reconnaissance and demolition operations, demonstrations, feints, raids, fire suppression during air strikes, and interdiction of coastal roads, railroads, airfields, and troop assembly areas. All these activities rest upon the same basic principles as the naval gunfire support of amphibious operations.

The basic task of naval gunfire support units in an amphibious operation is to support the seizure of the objective by destroying or neutralizing:

1. Shore installations that oppose the approach of ships and aircraft to the objective
2. Defenses that may oppose the landing
3. Defenses that may oppose the postlanding advance of troops

These tasks are carried out in the preparation of the objective for the landing, the support of the landing, and in postlanding support.

GUNFIRE CLASSIFICATION

Naval gunfire against land targets may be classified in various ways. These classifications are based on the effect sought, tactical use, technique of delivery, and type of fire. Each will be discussed in turn, by defining the terms used in each classification.

1. Effect sought:

a. **DESTRUCTION**. Deliberate and accurate fire, usually delivered at short range, for the purpose of destroying a target, usually a material object.

b. **NEUTRALIZATION**. Rapid, fairly accurate fire delivered for the purpose of hampering, interrupting, or preventing enemy fire, movement, or action. Destruction of weapons and personnel is secondary. The effect of neutralization comparatively temporary; such fire may have to be repeated.

c. **SUPPRESSION**. Used to deny the enemy use of selected weapons systems for a specific period of time, which will permit freedom of movement of friendly forces.

d. **HARASSING**. Sporadic fire delivered during otherwise quiet periods to prevent enemy rest, recuperation, or movement, and, in general, to lower enemy morale and combat efficiency.

e. **INTERDICTION**. Fire designed to prevent or curtail the use by the enemy of an area, bridge, defile, airfield, route of communication, etc.

f. **ILLUMINATING**. Gunfire employing illuminating projectiles (star shells) to illuminate the enemy, to detect his movements, to aid our own observation, or to facilitate own troop movements.

2. Tactical use:

a. **CLOSE SUPPORTING FIRE**. Gunfire delivered on enemy targets which, because of their proximity, present an immediate and serious threat to the supported unit. (Close supporting fire may be as close to friendly troops as 300 yards enfiladed, or 600 yards when the target axis is not parallel to the line of fire.)

b. **DEEP SUPPORTING FIRE**. Gunfire delivered on objectives not in the immediate vicinity of friendly forces, to neutralize or destroy enemy reserves and weapons, and interfere with enemy command, supply, communications, and observation.

c. **PREPARATION FIRE**. A heavy volume of prearranged neutralization fire, delivered just prior to a landing or a ground attack by friendly forces on enemy positions.

d. **COUNTER FIRE**. Gunfire delivered against active enemy guns and fire control stations for the purpose of silencing the guns.

e. **RECONNAISSANCE FIRE**. Gunfire delivered in areas where camouflaged positions are suspected or in vital areas where natural cover prevents observation and/or gathering of photo intelligence.

f. **SUPPRESSION OF ENEMY AIR DEFENSES (SEAD)**. Gunfire used to suppress AA fire immediately prior to and during an air attack on enemy positions.

g. **DEFENSIVE FIRE**. Gunfire delivered by direct and general support ships to protect against counterattack.

h. **PROTECTIVE FIRE**. Gunfire delivered by support ships during the period of reorganization after the capture of a position.

i. **SCREENING FIRE**. Gunfire that uses smoke projectiles to obscure the enemy's vision of own and friendly units and their deployment, movement, or maneuvers.

j. **COUNTERMECHANIZED FIRE**. Used against active enemy mechanized units.

k. **PREARRANGED OR SCHEDULED FIRE**. Gunfire formally planned and executed against targets of known location. Such fire is usually planned well in advance and is executed at a predetermined time.

l. **CALL FIRE**. Gunfire delivered at the request of troop units ashore, or of some spotting agency. Call-fire missions must not be interrupted without permission of the unit requesting the fire, except in case of emergency.

m. **OPPORTUNITY FIRE**. Gunfire delivered without formal planning or troop request on newly discovered targets, or upon transitory targets. Targets of opportunity may present themselves to the firing ship at any time, but fire must be delivered only with due regard for safety of friendly troops. Ships executing deep support missions must assure themselves that the target of opportunity is within their assigned sector of responsibility.

3. Technique of delivery:

a. **DIRECT FIRE**. Gunfire delivered on a target by using the target itself as a point of aim for laying the guns or director. Direct fire is usually used on targets that can be seen (by optics or radar) from the firing ship.

b. **INDIRECT FIRE**. Gunfire delivered on a target that is not itself used as a point of aim for laying the guns or director. Indirect fire is always used on targets not visible from the ship. This fire is spotted by air spotter or shore fire control party spotters assigned for this specific purpose.

4. Type of fire:

a. **AREA FIRE**. Gunfire delivered in a prescribed area. Area fire is generally neutralization fire.

b. **POINT FIRE**. Gunfire directed at a definite material target to destroy that particular target.

c. **DEFILADE FIRE** (reverse-slope fire). Gunfire delivered on targets located behind some terrain feature, such as a hill or ridge, which masks the target (fig. 10-5, view A).

d. **ENFILADE FIRE**. Gunfire delivered on a target in such a manner that the range pattern of the fall of shot coincides with the long axis of the target (fig. 10-5, view B).

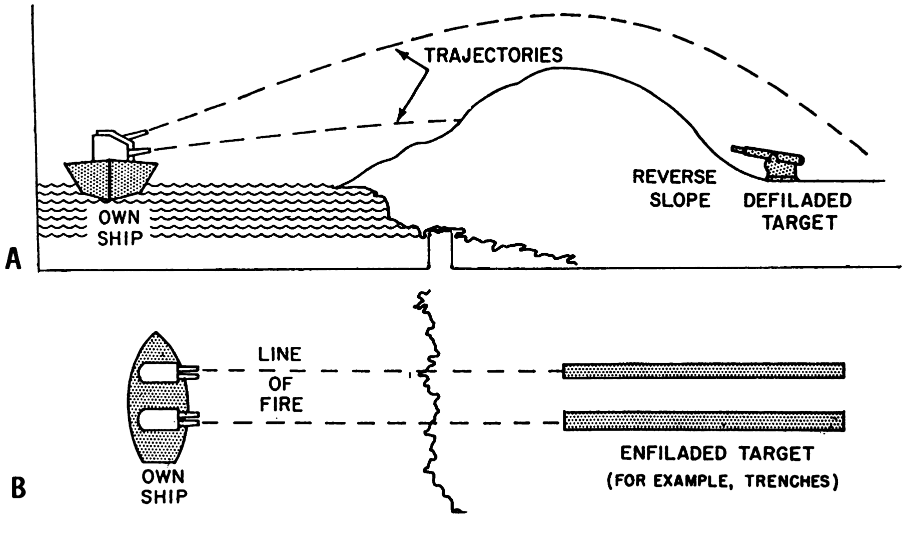

Figure 10-5.—Types of targets.

MILITARY GRID REFERENCE SYSTEM

Rapid and accurate means for designating the location of targets are important in shore bombardment, particularly in naval gunfire support of troop operations. It should be obvious that the troop unit supported and the supporting ship must use a common map. Although they need not be of the same scale, and seldom are, the target maps must be identical regarding terrain features and the method of locating points thereon. Like other techniques of naval gunfire support, the development of a system of target location designations has passed through several stages, generally following a grid-system method. Using this method, the land and sea areas at the objective are divided into squares by north-south and east-west lines, which are numbered. These lines are called grid lines.

The Military Grid Reference System superimposes vertical and horizontal reference lines on a projection of the earth's surface. Its purpose is to simplify the operation and increase the accuracy of reporting and plotting in military operations. This grid reference system is based on two projections: (1) the Universal Transverse Mercator (UTM), and (2) the Universal Polar Stereographic (UPS). The UTM is used in the area between 80° south latitude and 80° north latitude; the UPS is used in the polar regions of the earth south and north of these limits. The UTM system divides its area of the earth into a grid pattern with each rectangle in the grid 6° from east to west and 8° from north to south. (Because the grid is rectangular and the earth's surface is not flat, there is some distortion in maps based on the grid. In any single rectangle, however, this distortion is negligible.)

Each rectangle is called a grid zone, and is designated by a number and a letter (e.g., 2P, 5M, 52S, etc.). The grid zones are broken down into squares 100,000 meters on a side. These are further subdivided, with the smallest subdivision being a 100-meter square. The 100,000-meter square is identified by letters only. In the examples below, CU identifies the 100,000-meter square, and 52S identifies the grid zone. The subdivisions of the 100,000-meter square are systematically identified by letters and numbers, so that in theory any 100-meter square spot on earth can be designated by its number-letter code. This code is called a military grid reference, and it consists of a group of letters and numbers which indicate (1) the grid zone designation, (2) the 100,000-meter square identification, and (3) the grid coordinates (i.e., the numerical reference of the point expressed to the desired accuracy). Examples are as follows:

52SCU	Locating a point within a 100,000-meter square.
52SCU65	Locating a point within a 10,000-meter square.
52SCU6957	Locating a point within 1,000 meters.
52SCU693578	Locating a point within 100 meters.

As a matter of practical referencing in a shore bombardment problem, both the grid zone designation and the 100,000-meter square identification are generally omitted. The UPS system, in similar fashion, permits location and identification of any 100-meter square on the earth's surface near the poles.

Fire-support ships are provided with approach charts and bombardment charts for use on their dead-reckoning tracers. (A dead-reckoning tracer or DRT is a mechanical plotting device, usually located in CIC, that will trace own ship-track on a chart or plotting paper to any of a range of scales desired, using as inputs own-ship course and speed.) These charts are complete in hydrographic as well as topographic detail, and both have a grid system overprinted on them. These charts are of particular use in indirect fire (discussed later).

METHODS OF FIRING AT SHORE TARGETS

In conventional gunfire control, as described in chapter 9, the target is visible from the ship, either optically or by radar. But this is not always true of land targets; much of the firing any ship performs in shore bombardment will be at targets that nobody on the ship can see through a telescope or a radarscope. Fire at a visible target is called direct fire; fire at an unseen target is indirect fire.

Direct Fire

Targets visible from the firing ship offer the simplest fire control problem to the ship; their destruction is easier than targets that require indirect fire. Such visible targets are point targets, counterbattery targets, targets of opportunity, or area targets. When the target can be seen, the director can furnish accurate target bearing and elevation. These, with a present range which can be measured, ensure an accurate fire control setup which should result in early hits. Direct fire is controlled as it would be for fire against enemy ships, except that when the ship is providing call fire support, the spotter will locate the target, order the firing of the first round, and assist the ship in spotting when necessary. The ship will make its own corrections if visibility is good, and will end the mission. For a target that is acquired by the ship, control and spotting will be done entirely by the ship.

Indirect Fire: Use of Bombardment Charts

Indirect fire is employed against targets that cannot be seen by the firing ship. Given an accurate bombardment chart and knowing the exact position of own ship, it is possible to measure range and bearing to any land target that has been designated in advance, and to hit that target without using the director or rangefinder.

Indirect Fire: Point Oscar Method

This form of indirect fire is useful when no spotter is available. The method requires a visible point of aim (designated as "Point Oscar") near the target, as well as the accurate location of the target and Point Oscar on a map.

In practice, the director line of sight is kept continuously trained and ranged on the point of aim (Point Oscar) to give a continuous range and bearing solution to this point. Salvos are initially fired at Point Oscar as a check on the gun ballistics. As soon as the mean point of impact has been spotted to hit, range and deflection spots necessary to hit the invisible targets are applied.

Since the motion of the firing ship continuously changes the values of the offsets from the point of aim, frequent changes in these offset spots must be made to ensure hitting the target. This problem is illustrated in figure 10-6. One way to determine correct range and deflection spots continuously is to use a small transparent overlay with 100-yard squares inscribed on them, drawn to the same scale as the chart. With the center of the gridded overlay on Point Oscar, and the grid lines oriented to the direction of the line of sight from the ship, range and deflection spots to hit the designated target may be read directly from the grid overlay.

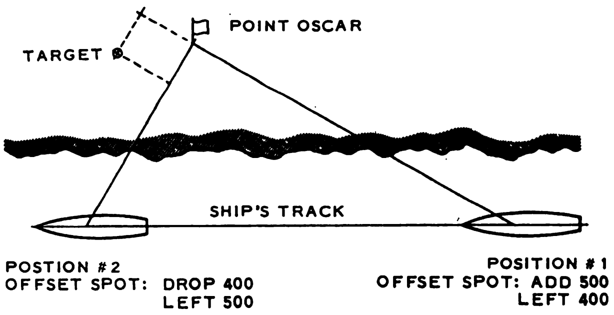

Figure 10-6.—Point Oscar method of indirect fire.

Indirect Fire: Radar Beacon

The radar beacon is a lightweight radar transponder used to aid in the delivery of accurate naval gunfire under all conditions of visibility. Emplaced and operated by a small team, the beacon provides an electronic reference point ashore from which a fire support ship can fix its actual or relative position. Use of the radar beacon can practically eliminate the navigation error element from initial salvo error.

There are three methods which may be employed using a radar beacon—method ALFA, method ALFA modified, and method BRAVO.

METHOD ALFA.—Method ALFA is used when the exact location of the beacon is known. In this method, the beacon is used simply as a navigation aid to determine the ship's position.

METHOD ALFA MODIFIED.—Method ALFA Modified is used when the exact location of the beacon is unknown, and when charts are not available. The target's coordinates are given by the spotter in relation to the beacon.

METHOD BRAVO.—Method BRAVO may be used whether or not the beacon location is accurately known. Target location is given in relation to the beacon, with the beacon being the point of aim, with offsets introduced into the computer to lay the gun on target.

Indirect Fire: Defiladed Targets

Targets that are located on the far slope of a hill or ridge between the firing ship and the target present a particularly difficult problem to the flat trajectory of naval gunfire. The projectile must clear the crest of the hill, but fall steeply enough to hit the target beyond. In this situation (defiladed target), an angle of fall must be chosen that is greater than the angle of the reverse slope. Two solutions are available. The ship may either increase the range, or it may use reduced-velocity charges at shorter range to obtain this selected angle of fall. Figure 10-7 illustrates this problem and its solutions. Trajectory A is produced by standard service charges and is too flat. Trajectory B can be obtained by using reduced-velocity charges. Trajectory C can be obtained with standard service charges by increasing the range.

If the ship must fire over friendly troops on an elevated position between firing ship and the target, it is necessary to determine target elevation, the elevation of the troop position, and the differences between the two.

Indirect Fire: Shift From a Known Point

This form of indirect fire is similar to the Point Oscar method. The difference is that this method is used with a spotter, allowing the ship to fire from a reference point without having that point in view. The ship must know the location and altitude of the known point—a previously fired and recorded target, or a reference point selected by the spotter and passed to the ship. To locate the target, the spotter identifies the known point and provides directions relative to the point along the observer target (OT) line, the lateral shift (left or right), the range shift (add or drop), the vertical shift (up or down), and how far the target is above or below the altitude of the reference point.

Indirect Fire: Functions of CIC

The primary function of CIC in naval gunfire support is to keep an exact check on the ship's position. From this check, CIC is to determine ranges and bearings to targets designated for indirect fire. CIC also keeps a record of own troop front-line positions, target locations, and other information pertinent to the support of the troops ashore. CIC acts as the clearing house for information to and from the shore fire control party and air observer. CIC has direct voice radio communication with the shore fire control party and air observer. In naval gunfire support, CIC keeps the ship's commanding officer, weapon control, and plot advised regarding the requirements for support. CIC also furnishes the information necessary to provide the support, and gives the shore fire control party such information as necessary. Target elevation is obtained from the spotter. However, it is a good practice for CIC to check that elevation and see if any terrain features "mask" the target.

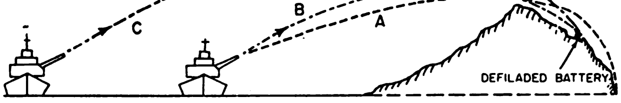

Figure 10-7.—Problem of hitting a defiladed target.

SPOTTING IN SHORE BOMBARDMENT

The principles of spotting as discussed earlier in this chapter apply in shore bombardment spotting, but the procedures are different when spots are made by a fire control party ashore.

A spotter ashore must be located where he can best observe the fall of shot. Usually this requires him to be as close as possible to the target; this can present him with a very serious frontline problem of survival. He also has an alignment problem. Spots made by an observer aboard the firing ship are naturally oriented to the line between the firing ship and target (gun target line or GTL). Spots made from aircraft can be oriented readily to the gun-target line, since both the gun and the target are normally within the aircraft observer's field of vision. But spotters ashore are frequently unable to see the firing ship and, so long as they are required to make their reports in relation to the gun-target line, the value of the information sent by the spotter to the ship is limited.

To simplify this problem for the spotter, the target-grid system for use in spotting the fall of shot on land is used. The target-grid system is part of the standard spotting and general shore bombardment procedure for use within the naval service.

The system permits the observer to spot the fall of shot, just as he sees it, along his own line of sight to the target (called the observer-target line or OT), irrespective of the position of the firing ship and of the gun-target line. This procedure is briefly outlined as follows (follow the graphic illustration of fig. 10-8):

1. The observer, in his call for fire, must give the bearing from himself to the target-direction (OT line in the illustration).
2. The observer makes all his observations and corrections with respect to the observer-target line (OT line).

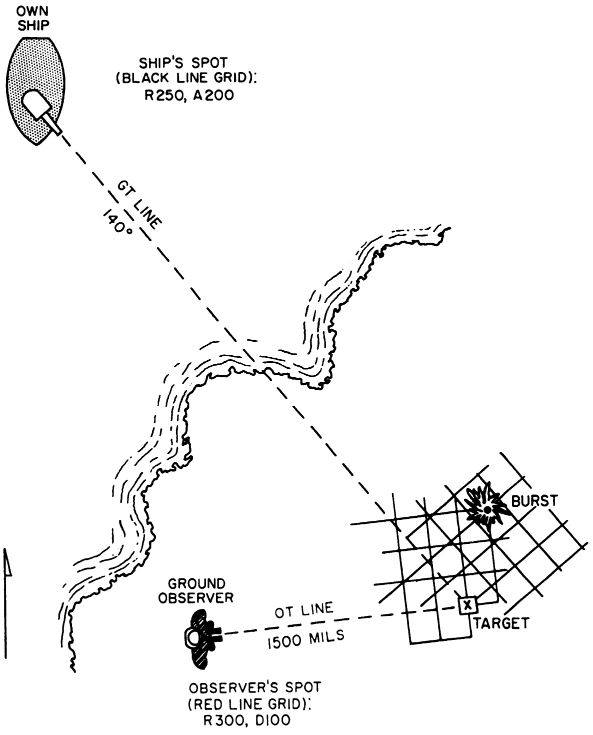
OWN SHIP
SHIP'S SPOT (BLACK LINE GRID): R250, A200
GT LINE
140°
BURST
GROUND OBSERVER
OT LINE
1500 MILS
TARGET
OBSERVER'S SPOT (RED LINE GRID): R300, D100

Figure 10-8.—Target grid spotting problem.

3. The CIC or plotting room crew converts the corrections of the observer to corrections with respect to the gun-target line (GT line).

4. The plotting room crew introduces into the range-keeper (computer) the spots corrected to the gun-target line.

The concrete example illustrated by figure 10-8 is explained in the next section.

APPLICATION OF THE TARGET-GRID SYSTEM

As stated in the preceding section, the target-grid system permits the ground observer to call his spots with respect to his own line of sight (OT line in figure 10-8), while spots introduced into the ship's fire control system are stated with respect to the ship's line of fire. The practical application of the target-grid system depends upon quick, accurate conversion from spots in terms of the observer's line of sight (OT line) to spots in terms of the line from gun to target (GT line). This is done graphically by the **grid spot converter,** which superimposes a set of coordinates based on the OT line over a set based on the GT line.

The converter (fig. 10-9) consists of a transparent circular plastic disc secured by a pivot

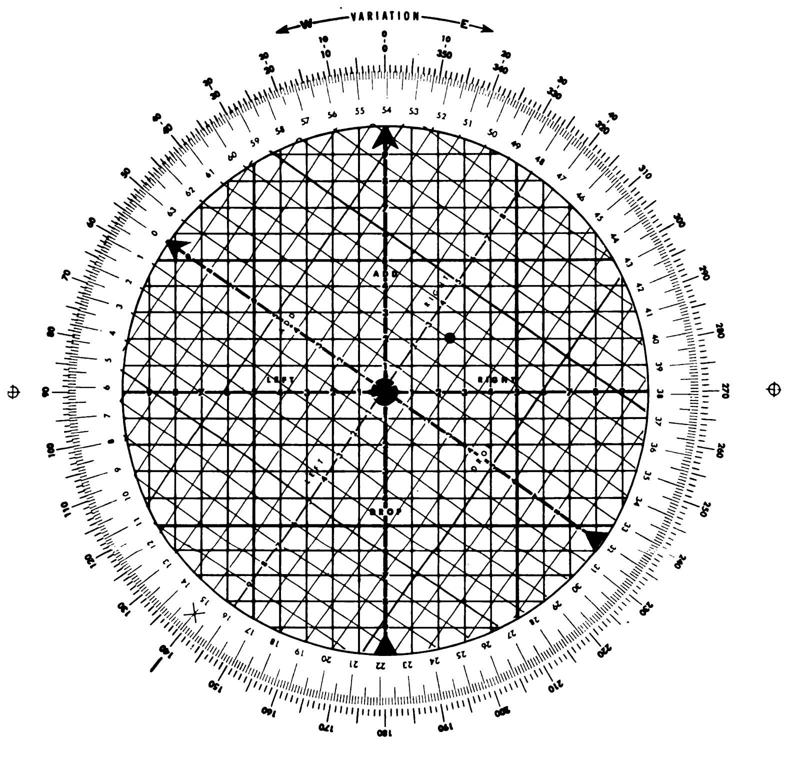

Figure 10-9.—Grid spot converter.

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at its center to a rectangular white plastic piece. Each is printed with a square grid pattern, with the squares on both pieces of equal size, with the words LEFT and RIGHT on either side, and the words ADD and DROP on the upper and lower parts. The grid lines on both pieces are numbered; each square represents an increment of 100 yards.

The grid pattern on the white plastic piece is printed in black and inscribed in a circle graduated counterclockwise in degrees; this represents the reference grid for own ship. On the 0-180 degree line of this pattern is a black arrow. At the top of the own-ship pattern appears an additional degree calibration for introducing magnetic variation correction.

The transparent pivoted disc has its grid pattern printed in red; the circumference of its circle (which is concentric with that of the own-ship pattern) is graduated counterclockwise in mils. A red arrow is on the 0-3200 mil line. This is the reference grid for the observer.

The procedure for using the converter is explained below. Figure 10-9 shows in red the part of the grid pattern that relates to the observer's spots; the black grid pattern relates to own-ship line of fire. Magnetic variation is assumed to be zero. The procedure following the spotting problem illustrated in figure 10-8 is as follows:

1. The converter operator obtains the true azimuth of the GT line in degrees by reading the true target bearing from the computer. He makes a mark with a grease pencil at this azimuth on the lower (black line) grid. He then obtains the azimuth of the OT line in mils or degrees (true, magnetic, or grid) from the observer (spotter) via CIC. He makes a mark at this azimuth on the upper (red line) grid.
2. The operator then rotates the upper disc until the two pencil marks match. (In the figure, the GT line is 140 degrees and the OT line is 1500 mils.) The red and black arrows now indicate the angular relationship of the observer's line of sight and the ship's line of fire.
3. When a spot is received, the operator starts at the center of the upper disc, which represents the burst, and plots the observer's spot, "Right 300; drop 100," on the observer's reference grid (red). The point plotted then represents the target, which is marked with grease pencil.
4. He now goes back to the burst (center) and counts off the squares to the target point as projected onto the lower disc (own ship reference grid). This gives a spot with reference to the ship's line of fire of "Right 250, add 200." This is the spot that is applied to the computer.

NAVAL GUNFIRE SUPPORT COMMUNICATIONS

Communications in shore bombardment is mainly external. Therefore, only the external aspect of this complex subject will be discussed in this section. We will do scarcely more than acquaint you with this specialty. Two- or three-day shore bombardment schools are available within the fleet for instructing a ship's "team" in the specifics of shore bombardment communications and procedures.

Before we begin our discussion on gunfire support communications, some terms will have to be explained. The terms given in the following paragraphs are used in various stages of gunfire support between the support ship and the spotter.

DANGER CLOSE.—Indicates that friendly forces are within 750 meters of the target for guns smaller than 6 inches, within 1000 meters of the target for guns 6 inches and larger (except 16 inch), or 2000 meters of the target for 16-inch guns.

FIRE FOR EFFECT.—A method of control given when the MPI of delivered fire is within the desired distance of the target or adjusting point.

SPOTTER ADJUST.—A method of control in which the spotter controls the mission and is responsible (1) for the adjustment of the MPI onto the target and (2) for requesting the appropriate number of guns and salvos in fire for effect.

SHIP ADJUST.—A method of control used when the spotter desires the ship to engage a target using direct fire and to adjust its own fire.

CHECK FIRE.—An order used to interrupt firing temporarily.

CHECK SOLUTION.—An order to the ship to check the fire control solution. Generally sent by the spotter when an excessive salvo-to-salvo error trend is observed.

REPEAT.—An order to fire again, the same number of rounds, with the same method of fire, at the same target location.

NEGLECT.—Term used by a ship to indicate that the last salvo was fired with incorrect settings.

CREEPING.—A method of adjusting fire in which successive adjustments are moved closer to the target in increments of 100 meters. Used in danger close procedure.

SHOT.—A report by the ship indicating the moment of firing.

SPLASH.—A report transmitted by the ship 5 seconds before the estimated time of detonation of a salvo.

POLAR PLOT.—A target location method whereby the spotter locates the target in relation to his position by providing a direction and distance to the target. The spotter's exact position must be known by the fire support ship.

AT MY COMMAND.—An order used by the spotter to indicate that he desires to regulate the exact time of firing. The ship reports READY and awaits the spotter's order to fire each salvo.

DIRECTION.—The reference direction from which all corrections are called by the spotter, either along the observer-target (OT) line or the gun-target (GT) line.

Once a fire support ship is on station and available for fire, any spotter in the assigned sector can call on the ship for fire support. Calls for fire are submitted over the established radio/telephone voice network in the following format:

1. Spotter identification
2. Warning number and target number (break)
3. Target location:
   a. By grid coordinates
   b. By polar plot
   c. By shift from a known point
4. Direction
5. Target description
6. Method of engagement
   a. Type of ammunition and fuze used
   b. Number of salvos
   c. Other special instructions
7. Method of control
   a. SHIP ADJUST
   b. SPOTTER ADJUST
   c. AT MY COMMAND

To illustrate an instance of the use of external communications in shore bombardment, table 10-1 shows an example of the voice communications between shore spotter and ship in a simple spotting operation.

ADVANTAGES AND LIMITATIONS OF NAVAL GUNFIRE SUPPORT

Naval gunfire support has several advantages as well as some limitations for troop support in landings. The advantages include:

1. **AVAILABILITY.** Gunfire support ships are continuously available before, during, and after the landing as long as the zone of action ashore is within the range of the ship's guns.

2. **MOBILITY.** Within the limitations of navigation, ships can move rapidly from one area to another as the situation ashore develops. At the same time, the most favorable ranges and lines of fire can be fully exploited, and enemy counterfire can be evaded.

3. **HIGH RATE OF FIRE.** Power loading and mechanical ammunition supply make it possible to deliver a large volume of fire in a short time. This characteristic is of great value in neutralization missions, where it is necessary to saturate the target area with a large volume of fire.

4. **HIGH MUZZLE VELOCITY AND FLAT TRAJECTORY.** Naval guns, particularly those of heavy caliber, have great penetration and destructive power, especially against installations presenting vertical surfaces.

5. **SMALL DEFLECTION PATTERN.** The comparatively small dispersion in deflection of naval guns makes them valuable for close support of troops when the line of fire can be made parallel to the troops' front line (enfilade fire).

Tactical employment of naval gunfire in support of troops also has certain limitations, which must be considered in both planning and operational stages. The most important limitations are given in the following paragraphs.

1. **NECESSITY FOR OBSERVATION.** Naval gunfire, except for area fire on very large targets, must be observed and corrected to be effective. This requires a spotting agency, such as a ground, air, or shipboard spotter.

2. **NAVIGATIONAL LIMITATIONS.** Ships are forced to remain in safe, navigable, mine-free waters, and therefore sometimes cannot take advantage of the positions most favorable for the attack of targets. In some cases, ships cannot fire at all on certain defiladed (located on a reverse slope) targets. Obviously, the maximum range inland is limited by the position of the ships, as well as by the characteristics of the weapons used. Further, the fact that the ship is in motion requires

Table 10-1.—Sample Spotting Communication

SERIAL	FROM	VOICE	REMARKS
1	ALLOTTED SPOTTER	Y2P THIS IS C5E FIRE MISSION TARGET NUMBER AF 0004 . . . OVER	Transmission is broken after target number.
2	NAVAL GUNFIRE SHIP	C5E THIS IS Y2P FIRE MISSION TARGET NUMBER AF 0004 . . . OUT	
3	SPOTTER	FROM REFERENCE POINT 01 DIRECTION 0510 RIGHT 240 ADD 400 UP 35 TROOPS IN TRENCHES FUZE TIME IN EFFECT SPOTTER ADJUST . . . OVER	Shift from a known point. Direction is understood to be mils grid. Altitude is understood to be meters. Spotter desires fuze time in effect.
4	SHIP	(READ BACK) . . . OUT	
5	SHIP	GUN-TARGET LINE 2050 READY 14 . . . OVER	Gun-target line is understood to be mils grid.
6	SPOTTER	GUN-TARGET LINE 2050 READY 14 . . . FIRE . . . OVER	
7	SHIP	FIRE . . . OUT	
8	SHIP	SHOT . . . SPLASH . . . OUT	
9	SPOTTER	RIGHT 100 ADD 200 . . . OVER	Spotter adjusts to establish bracket.
10	SHIP	(READ BACK) . . . OUT	
11	SHIP	SHOT . . . SPLASH . . . OUT	
12	SPOTTER	LEFT 30 DROP 100 FUZE TIME . . . OVER	Spotter starts to adjust fuze time after splitting 200-meter bracket.
13	SHIP	(READ BACK) . . . OUT	
14	SHIP	SHOT . . . SPLASH . . . OUT	
15	SPOTTER	UP 40 . . . OVER	Initial fuze time burst was graze.
16	SHIP	(READ BACK) . . . OUT	
17	SHIP	SHOT . . . SPLASH . . . OUT	

Table 10-1.—Sample Spotting Communication—Continued

SERIAL	FROM	VOICE	REMARKS
18	SPOTTER	DOWN 15 10 SALVOS FIRE FOR EFFECT . . . OVER	Air burst was obtained. Down 15 is transmitted to achieve 20-meter height of burst.
19	SHIP	(READ BACK) . . . OUT	
20	SHIP	SHOT . . . SPLASH . . . OUT	
21	SHIP	ROUNDS COMPLETE . . . OVER	
22	SPOTTER	ROUNDS COMPLETE . . . OUT	
23	SPOTTER	20 SALVOS SUSTAINED FIRE 5 MINUTES REPEAT . . . OVER	Spotter desired 20 salvos fired over a 5-minute period on the last fire-for-effect data.
24	SHIP	(READ BACK) . . . OUT	
25	SHIP	SHOT . . . SPLASH . . . OUT	
26	SHIP	ROUNDS COMPLETE . . . OVER	
27	SPOTTER	ROUNDS COMPLETE . . . OUT	
28	SPOTTER	END OF MISSION 20 CASUALTIES . . . OVER	
29	SHIP	(READ BACK) . . . OUT	

the continuous and accurate fixing of the ship's position for delivery of fire—on targets not visible from the ship.

3. **COMMUNICATION LIMITATIONS.** Radio and visual communications between ship and shore are not as flexible, reliable, or secure as communications by wire or telephone.

4. **LIMITATIONS OF PATTERN.** By comparison with artillery, naval guns have a small deflection pattern, a large range pattern, and a flat trajectory. This is an advantage in some respects, but requires careful selection of lines of fire when engaging targets near our own troops. As stated earlier, the difficulty of fire against defiladed targets may be overcome by using reduced-velocity charges or by increasing the range to obtain a greater angle of fall.

5. **LIMITED AMMUNITION CAPACITY.** The limited capacity of the ship's magazines, coupled with the fact that a ship must always contain a certain amount of ammunition for its own protection, restricts the ability of any one ship to maintain uninterrupted support over an extended period of time. This disadvantage may be overcome by providing adequate ammunition replenishment and by rotating ships assigned to support missions.

SELECTION OF WEAPONS

Selection of the guns or weapons to be used in naval gunfire support is determined by the nature and size of the target to be engaged, and by the proximity of friendly troops to the target. For each class of ship, there is a publication in the NWP-65 series that governs the appropriate application and tactical use of its weapons systems. This publication is classified.

Selection of Gun Size

The 5-inch gun is normally used for close support in fire; its rapid rate of fire and relatively small pattern size make it an excellent weapon for neutralization and destruction of targets immediately in front of advancing troops. Destroyers are usually assigned close-supporting fire duties because their maneuverability permits them to shift positions easily and quickly, and take positions close inshore for direct fire on targets in coastal areas.

Sixteen-inch guns, with their great accuracy at long range, are normally reserved for deep supporting fire. The lethal bursting radii of projectiles from these guns limit their employment in close support. Moreover, ships mounting these guns (battleships) are hampered in responding quickly to fire commands because they are less maneuverable than destroyers, and their fire control organization is more complex. The larger ships also have additional duties. The destructive power of large-caliber projectiles makes them particularly effective against heavy installations ashore.

Three-inch and 76-mm guns are effective for area neutralization where heavier guns are not required. They are particularly effective against shore-line targets.

Selection of Projectile Type

Selection of the projectile type to be used in support of troops depends upon the type of target and the effect sought on that target. In shore bombardment, a battery is likely to be shifted frequently and rapidly from one target to another. The type of target may also change, requiring a change in ammunition. Ammunition-handling personnel should be prepared to change projectiles on very little notice.

Each type of projectile is equipped with a fuze selected to meet a specific objective. (Projectile fuzes can not be changed by fleet personnel.) Mechanical time fuzes are used to provide air burst for maximum effect against personnel and light equipment. They should be set to burst 60 feet directly above the target. Proximity fuzes, which require no advance setting, accomplish the same purpose with greater accuracy and less difficult fire control, because they compensate automatically for variations in ground elevation. Point-detonating fuzes also require no advance setting, but produce a lower and more concentrated burst, often desirable for demolition. Base-detonating fuzes are, of course, required against armored or other heavy structures. Navy gun projectiles and their fuzes are described in detail in the Naval Sea Systems Command publication, *Navy Gun Ammunition*, SW030-AA-MMO-010.

TARGET INTELLIGENCE

Before the undertaking of any bombardment of land targets, a thorough familiarity with the terrain and hydrographic features of the objective, and knowledge of the location of profitable targets must be acquired. The study of available charts, maps, aerial photographs, radar PPI simulations, mosaics, and other pertinent information will be necessary for rapid, effective troop support. Normally, these charts, maps, photographs, and target information will be furnished each fire support ship prior to the operation. The systematic destruction of defenses requires the continuous assembly and evaluation of targets known beforehand as well as those discovered in the course of the operation. Damage assessment must be based upon visual observation and photoanalysis. A common error is over-optimism as to the effectiveness of naval fire against land targets.

PHASES OF NAVAL GUNFIRE SUPPORT OPERATIONS

It is convenient to divide naval gunfire support for a landing operation into three general phases as follows:

1. **PRELANDING.** This phase, which may commence well in advance of D-day, uses quick raids by surface ships to inflict damage and cause confusion, after which the ships retire. Similar strikes may be carried out by aircraft during this phase.

More often, the bombardment group will move into position a few days prior to D-day. It will commence its schedule of prearranged fire, which may continue right up to H-hour (the time of landing of the first wave of troops), or may be interrupted by retirement of the bombardment group for reasons of safety.

During this period, the effect sought by the bombardment is destruction of beach defenses, gun control, and observation posts, or any defenses that could effectively oppose the landing. Slow, deliberate, close-range destructive fire is used whenever possible. In this and later phases, the identity of the actual landing beaches may be concealed by a schedule of fire covering other areas. The number of ships engaged in the prelanding bombardment, its duration, and the type of ammunition expended will depend upon such factors as the number of ships and planes available, logistics (especially ammunition supply), and the nature of the terrain and its defenses.

In addition to its primary purpose of destroying designated targets that may hamper the landing, the force may provide cover for minesweepers, underwater demolition teams, and oceanographic survey vessels. During the night, it may engage in harassing fire. During the last hours prior to H-hour, it may be called upon for interdiction fire to prevent assembly of reinforcements and prevent their movement into the area of the beaches to man or repair the equipment. On D-day, before the troops embark, bombardment of strong resistance points is intensified.

The force may also cover final minesweeping operations and the approach of the attack force, especially the transports. When transports are in position off the landing beaches, fire can be concentrated on strong points that intelligence reports or observations indicate have not been destroyed.

During this period, air strikes are often scheduled to bomb and strafe the beaches. Provisions must be made to control fire to avoid hitting friendly planes.

2. **LANDING SUPPORT**. The primary missions of naval gunfire in this phase are to protect the transports, while the landing force is embarking in boats, to silence batteries that might destroy the assault waves as the boats move in to the beach, and to cover the actual landing of troops. The barrage must be lifted inland or shifted to the flanks, as the troops near the beach, to avoid hitting the landing force and to neutralize strong points from which destructive crossfire could rake the beaches. In addition to close-supporting neutralization fire on the landing and adjacent areas, deep supporting fire must concurrently prevent enemy troop movement toward the landing area and neutralize more remote opposing enemy defenses.

During the last few minutes, as the first wave nears the beach, a final air strike often parallels the beach, strafing and driving the enemy to cover. Things happen so fast, and communications with the troops being supported are rarely adequate in the critical period during and immediately following a landing. Most of the supporting fire must be planned in advance; delivery should be accomplished according to a carefully formulated and well-coordinated time schedule.

3. **POST LANDING AND TROOP ADVANCE PHASE.** Naval gunfire is employed after the landing phase to assist the advance of troops to their final objectives. The postlanding fire schedule must be carefully planned and coordinated with the estimated troop advance. At the same time, the schedule must allow for quick modification to permit repeating, extending, or discontinuing any portion of the schedule when the advance differs from the plan. Close- and deep-supporting fire must be scheduled to continue after the landing to neutralize enemy opposition that would hinder the rapid establishment of organized troops ashore. Scheduled fire after H-hour must last well beyond the estimated time required to establish effective naval gunfire control agencies ashore. With heavily defended objectives, scheduled fire for close support must continue at least an hour after the landing; for deep support, scheduled fire should continue for at least 4 hours.

Close-supporting fire from ships assigned to them, either daily or upon special request, is made continuously available to troop units in the assault. Deep support, including daily destructive fire missions, preparation fire for troop attacks, and night harassing fire, is scheduled for daily execution in fulfillment of troop requests. This phase of naval gunfire support begins upon completion of the prearranged scheduled fire in support of the landing, and continues until naval gunfire is no longer required for support.

SUMMARY

In this chapter we have discussed general spotting techniques, as well as some of the tools used in spotting, such as the grid spot converter. We have also described how these spotting procedures are used in naval gunfire support. Again, this chapter is intended to give you a general view of the tactical use of naval gunfire and is not to supplant CNO or other command directives on the subject. Specific information on all phases of gunfire support in amphibious operations is contained in NWP 22-2 (latest revision).

REFERENCES

Allied Spotting Procedures for Naval Gunfire Support, ATP-4(B), Department of the Navy, Office of the Chief of Naval Operations, Washington, D.C., 1984.

Supporting Arms in Amphibious Operations, NWP 22-2 (Rev. A), Department of the Navy, Office of the Chief of Naval Operations, Washington, D.C., 1980.

CHAPTER 11

INTRODUCTION TO COMBAT SYSTEM ALIGNMENT

Thus far we have described the elements that make up a modern combat system. These elements must work together with a great degree of accuracy to deliver ordnance on target. All are electrically and/or mechanically linked to pass data from one unit to the next. To ensure a correct exchange of data between the various systems, each equipment with alignable properties must be aligned to a common reference. Data transmission and response synchros must be properly zeroed. All gun bores, missile launchers, fire control directors, radar antennas, gyro compasses, and other similar pointing lines must be parallel (when no parallax or ballistic corrections have been made). Combat system alignment is the process of establishing parallelism, within acceptable tolerances, between the elements of the combat system.

In this chapter we will describe the sequence used in establishing combat system alignment. We will then discuss the more familiar sequence of alignment verification. Finally, we will describe the function and make up of the combat system smooth log.

ALIGNMENT PRINCIPLES

Combat system alignment begins with the design of the ship. Alignment is established as the ship is constructed. Once constructed, alignment is continually perfected up to the point where the ship is placed in commission and its permanent operational crew is on board. As a ship goes through its normal life cycle, it is the job of the crew to continually verify this alignment, making corrections as necessary. Alignment verification is discussed in the next section of this chapter.

SEQUENCE OF ALIGNMENT

There are certain steps in a combat system alignment process that must be accomplished according to a specified sequence. The sequential steps are as follows:

1. Establishment of reference planes
2. Establishment of reference marks
3. Establishment of parallelism
4. Performance of fire control radar radio frequency (RF)—optical alignment
5. Performance of train and elevation alignment
6. Establishment of bench mark and tram reference readings
7. Performance of dynamic train alignment

Establishment of Reference Planes

The first major alignment step is the establishment of reference planes. As we said in chapter 9, a position can only be described by relating it to a known reference point. Reference planes allow combat system elements to be described as to how they are situated in relationship to each other. Reference planes are established during the initial construction of the ship and are used as required during alignment of the combat system. Reference planes consist of the centerline reference plane (CRP), the ship base plane (SBP), the master reference plane (MRP), and the weapon control reference plane (WCRP).

CENTERLINE REFERENCE PLANE.—The centerline reference plane (CRP) is the first plane established. It is the plane containing the ship centerline and is perpendicular to the ship base plane (SBP). The CRP is the reference used to establish train zero alignment of all combat system equipment.

SHIP BASE PLANE.—The ship base plane (SBP), the basic plane of origin, is perpendicular to the CRP, and includes the baseline of the ship, but is not necessarily parallel to the keel.

MASTER REFERENCE PLANE.—The master reference plane (MRP) is a plane within the ship parallel to the SBP. On most ships, the MRP is represented by a master level plate that has been accurately leveled to the SBP and aligned in bearing to the CRP. The master reference plane is used as the machining reference to establish the foundations of combat system equipment. After initial construction alignment, the MRP is only used as a reference plane following major damage or modernization.

WEAPON CONTROL REFERENCE PLANE.—The weapon control reference plane (WCRP) is established during initial construction and is usually represented by the roller path plane (RPP) or the equipment that has been designated the alignment reference. This is the plane most people are familiar with that are involved with alignment verification. On the FFG-7 class ship, for example, the WCRP is the roller path of the Mk 75 gun mount.

Establishment of Reference Marks

The second major alignment step is the establishment of reference marks. Reference marks include centerline reference marks, offset centerline reference marks, and equipment bench marks.

CENTERLINE REFERENCE MARKS.—Centerline reference marks are established during initial construction to represent the ship's centerline. Several small plates (at least two forward and two aft) will be installed at intervals along the centerline to indicate its location.

OFFSET CENTERLINE REFERENCE MARKS.—Offset centerline reference marks are also established during initial construction to facilitate combat system alignment. The offset centerline is established parallel or perpendicular to the ship's centerline. These marks are installed to preclude repeating the centerline survey during subsequent alignment. They must be maintained within one minute of arc of the centerline reference plane (CRP).

BENCH MARKS.—Bench marks are the most familiar of all the reference marks to the average equipment operator/maintenance man. A bench mark is installed for each equipment that has an alignment telescope. They are installed at any convenient location that is visible through the equipment telescope. Equipment bench marks are used throughout the life of the ship to verify alignment.

Establishment of Parallelism

The third major alignment step is the establishment of parallelism between the roller path planes (RPPs) of all the equipments in the combat system. This step is also accomplished during initial construction. It is accomplished again as new systems are added or old equipment is replaced. The steps necessary to achieve the required degree of parallelism are foundation machining, inclination verification, and interequipment leveling.

FOUNDATION MACHINING.—Before combat system equipment is installed aboard ship, the equipment foundations are machined so that the planes of the foundations are parallel, within tolerance, to the reference plane and then smoothed to the required flatness.

When the equipment is mounted aboard ship, the RPPs will not be precisely parallel. It is not possible, under normal conditions, to attain perfect accuracy in machining or in the construction of equipment. There will always be some error. However, once machined within tolerance, there are devices incorporated into most equipments that can be adjusted to compensate for roller path alignment error. These are discussed later in this chapter.

INCLINATION VERIFICATION.—Inclination verification consists of the measurement of the tilt between equipment roller path planes of the equipment in the combat system and the reference plane. Figure 11-1 shows a plane tilted with respect to the reference plane. Note that the inclination varies with the bearing. In the direction of line OA, the inclination is zero. Inclination increases gradually, in the direction of line OB, until it reaches maximum positive angle at 90 degrees from line OA. Point B is the **bearing of the high point (Bhp)**. Point D is a negative angle, proportionate to the positive angle of point B. All references to roller path alignment are expressed in terms of the bearing and inclination of the high point. The tilt of the RPP is determined by using clinometers or similar devices.

INTEREQUIPMENT LEVELING.—Equipment leveling is accomplished through the use of leveling rings, shims, adjusting screws, equipment adjustments, or offset by software.

A common device used to offset the effects of roller path misalignment is the roller path compensator. The roller path compensator is incorporated into the elevation receiver-regulator of most gun mounts. It is connected, through

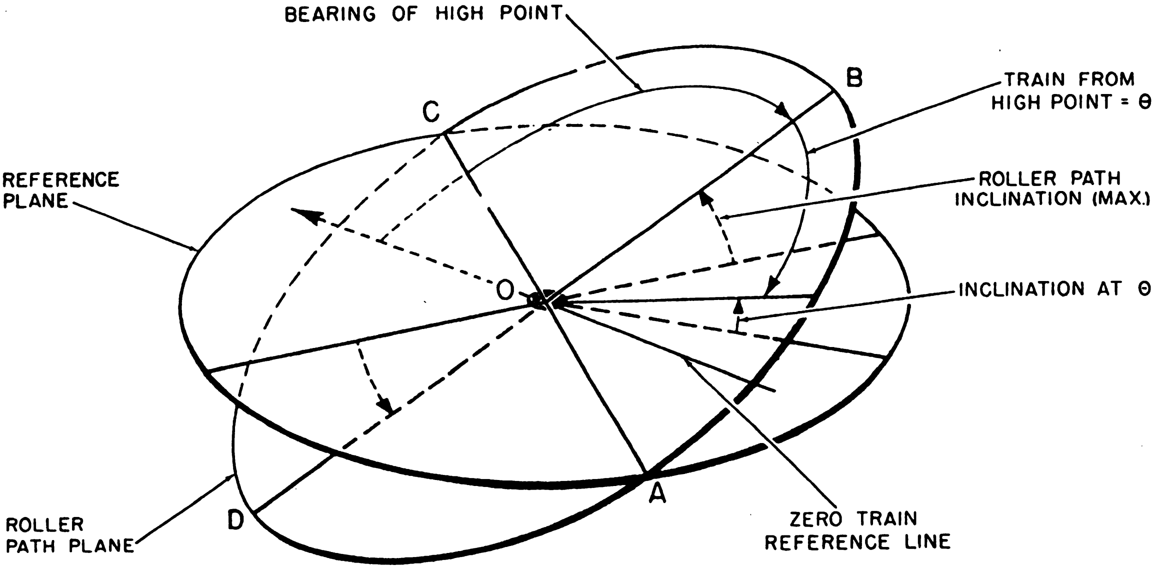

BEARING OF HIGH POINT
B
TRAIN FROM HIGH POINT = θ
C
REFERENCE PLANE
ROLLER PATH INCLINATION (MAX.)
O
INCLINATION AT θ
A
ROLLER PATH PLANE
D
ZERO TRAIN REFERENCE LINE

Figure 11-1.—Variation of roller path inclination with bearing.

gears and linkages, to the train drive unit. The roller path compensator is set with the bearing and magnitude (in minutes) of the high point. As the gun moves in train, the compensator is moved, and either adds or subtracts from the elevation order the number of minutes necessary to cancel out the roller path error at that bearing. For further information on roller path alignment, see NAVSEA OP-762, chapter 5.

Performance of Fire Control Radar RF-Optical Alignment

The fourth major alignment step is the verification of fire control RF-optical alignment (collimation). This is the alignment between the axis of the RF energy beam emitted by the fire control radar and an optical device attached to the radar antenna. During initial installation, the alignment is established and the optics are secured in place. During subsequent alignment checks, adjustments are made to correct any errors detected. Radar collimation checks are normally conducted using a certified shore tower facility. Some radars however, may be collimated while tracking a target. Figure 11-2 illustrates the essence of radar collimation.

Performance of Train and Elevation Alignment

The fifth major alignment step is the performance of train and elevation alignment. This

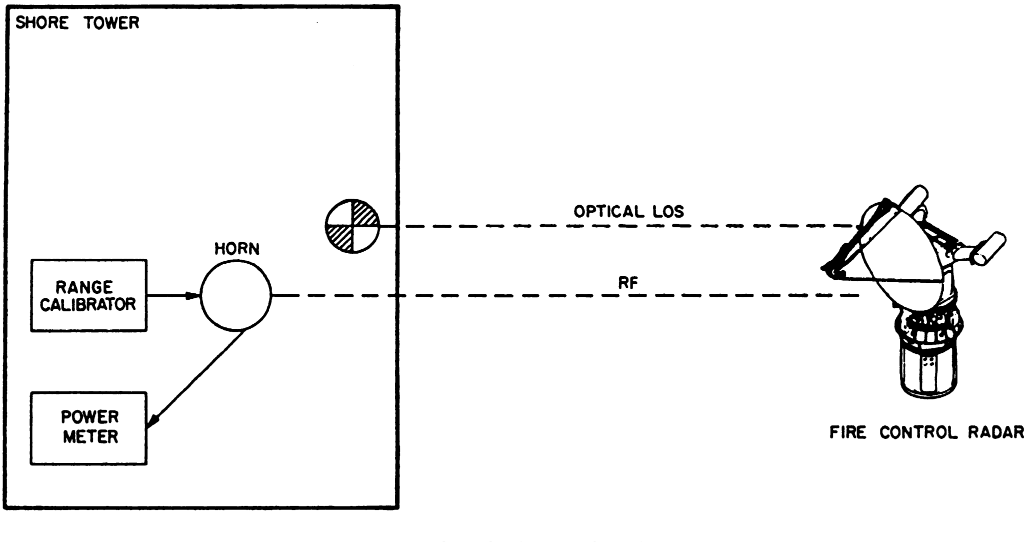


Figure 11-2.—Radar collimation.

alignment is performed by fleet support personnel to ensure that the pointing lines are parallel. This procedure is the same one performed by fleet personnel to verify system alignment. There are two procedures that can be used for train and elevation alignment. The first is the establishment of train and elevation zero (theodolite method); the second is the train and elevation space alignment (star check method).

The theodolite method aligns train zero to the centerline reference plane and elevation zero to the equipments roller path plane. The more familiar star check method establishes parallelism between combat system elements by having them all sight on a celestial body, then aligning their dials to match those of the weapons control reference plane (WCRP). The star check method will discussed further in the next section of this chapter.

Establishment of Bench Mark and Tram Readings

The sixth major alignment step is the establishment of bench mark and tram reference readings to furnish an easy means of verifying the alignment of equipment in the future. It is necessary to have reference readings because the equipment position data dials, and data transmission synchros may become misaligned due to wear, vibration, or normal maintenance. These reference readings are normally established by ship yard or NAVSEA representatives after all system elements are aligned. The application of these reference readings will be discussed further in the next section of this chapter.

Performance of Dynamic Train Alignment

The last major step is the train alignment between the reference and alignable combat system equipment not equipped with a telescope. This is accomplished by comparing equipment position with the position of the alignment reference, while simultaneously tracking an isolated target. Fleet and fleet support personnel conduct this alignment.

These steps are used to establish combat system alignment. Shipboard personnel, are not usually directly involved in most of this process. What we have described thus far is what takes place while a ship is being constructed or in a major overhaul. Once established, it is the responsibility of shipboard personnel to verify and maintain the alignment of the system. This is the part of combat system alignment that is more familiar to most fleet personnel.

ALIGNMENT VERIFICATION

There are several procedures that are fundamental to alignment verification. In this section we will describe a typical gun mount alignment verification procedure, including tram and bench mark readings and star checks. Since each system is configured differently, we will not attempt to explain in any detail how corrections are actually made.

TRAM AND BENCH MARK READINGS

Once established, tram and bench mark readings give the maintenance man a ready reference to check the alignment of the equipment. A piece of equipment will be fitted either for tramming or with a fixed telescope for sighting a bench mark. Typically, gun mounts and missile launchers are trammed, while directors are aligned to bench marks. Some systems, however, may be fitted for both.

Tram

A gun mount is fitted with two sets of tram blocks—one set each for train and elevation. The blocks are welded, one to the rotating element and the other to a stationary element nearby. Elevation tram blocks are attached, one to the underside of the slide and the other to the carriage. Train tram blocks are attached, one to the bottom of the carriage and the other to the stand. Tram blocks are provided with machined pins with cupped ends that fit the ends of the tram bar. The telescoping tram bar is the most common type in use, and will be the only type discussed here. The bar consists of two parts, one sliding inside the other. The parts have a small movement with respect to each other and are extended by an internal spring. A scribe mark on the inner part is visible through an opening in the outer part. Engraved on the edges of the opening is a zero mark. When the inner scribe mark and the outer zero mark are aligned, the tram bar is at the correct length. The tram bar is placed in the tram blocks and the gun mount is trained or elevated to compress or expand the bar until the marks are aligned. This serves to place a known distance between two fixed points, corresponding to a specific train or elevation angle. Once this angle is determined, it becomes the reference for future alignment verification.

Figure 11-3 illustrates a tram bar installed in a set of gun mount train tram blocks. Tram readings are taken as an average of several readings. The air drive motors are used to move the gun mount. Several readings are taken, moving the mount to compress the tram bar into alignment; a like number of readings are taken moving the mount to extend the bar into alignment. By moving the gun mount in both directions, any lost motion in the gear train can be detected. Elevation tram readings are always taken with the gun mount trained to 90 degrees from the bearing of the high point. At any other train bearing you will get erroneous elevation readings, due to the offsetting inputs of the roller path compensator. The readings are then averaged and compared to the reference readings, which are inscribed on a plate normally attached to one of the trunnion supports.

Bench Mark

The bench mark is used much the same as tram readings. The equipment to be aligned trains and elevates to align the telescope crosshairs with the bench mark. The bench mark, however, may be some distance from the equipment you are aligning. This increases the probability that the bearing to the bench mark will change in relation to your equipment due to hull distortion. No alignment adjustments should ever be performed based on a single tram or bench mark reading.

STAR CHECKS

Star checks are used to verify parallelism between elements of the combat system and the WCRP. To illustrate this process, we will assume that the gun director is also the WCRP. We will now align the gun mount to the director. To begin with, the gun is fitted with a bore scope and all ballistic and parallax corrections are set at zero. The bore scope is inserted into the breech of the gun, and its cross hairs aligned with the axis of the bore. In the evening, a celestial body (star) is selected, and the director is moved to track the star with its optics. The gun is driven simultaneously, with the air drive motors, to track the same star through the bore scope. Once the star can be seen through the optics of both the gun and the director, each is moved to pass the vertical or horizontal cross hair over the star. When the star is centered in the cross hair, the man at the telescope gives a ''mark.'' When both the director and the gun ''mark'' at the same time, all movement is stopped and the dials are read. This is done several times from each direction: from the bottom and the top in elevation, and from the left and the right in train. Each crew then averages their train and elevation readings

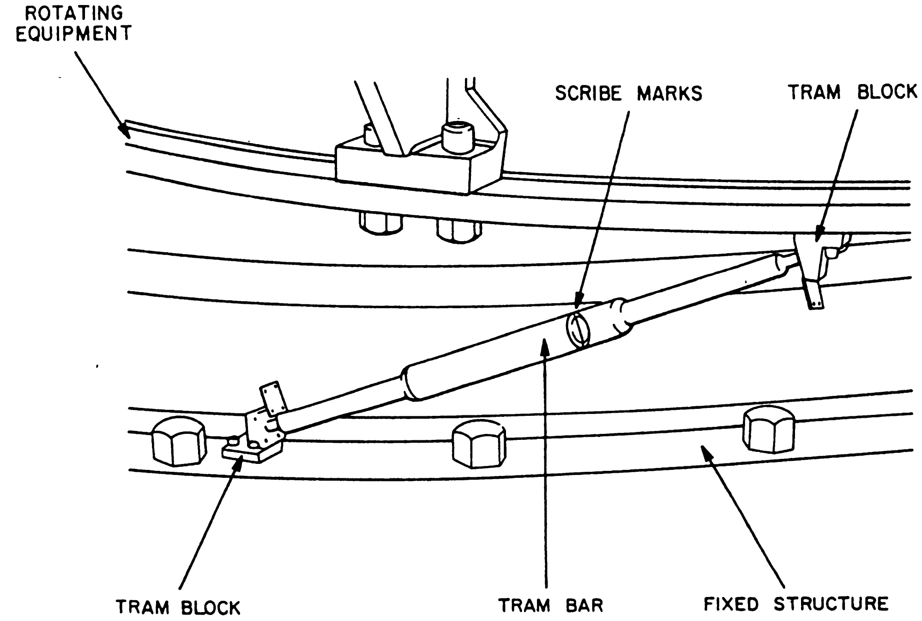


Figure 11-3.—Tram bar and tram blocks.

Table 11-1.—Smooth Log Data and General Outline

Data	S	G	M	U	N
Section A - Alignment					
a. Record of checks (changes if any), dates held, and methods used	X	X	X	X	X
b. Collimation data dates and results of radar antenna and X beam alighment	X	X	X		
c. All plots of roller path, cutout cams and zones (firing) and radiation), and horizon checks	X	X	X	X	
d. Bench mark readings and plate locations, tram readings (including bearing of mount for elevation tram, when applicable)	X	X	X	X	
Section B - Calibration					
a. Double echo checks and resultant settings		X			
b. Sonar calibration and source levels				X	
c. Divergence					X
Section C - Rangefinder calibration					
a. Record of rangefinder calibration checks and adjustments		X			
b. A curve for rangefinder, and a smooth copy of each operator's B curve		X			
Section D - Erosion					
a. Star gauge data		X			
b. Records of erosion gauge readings		X			
c. Records of bore searches		X			
d. Equivalent service rounds		X			
Section E - Rounds fired					
Entries in tabular form for each gun and/or launcher showing rounds fired, projectile, powder charge, etc.		X	X	X	
Section F - Firing reports					
File of all firing reports kept in chronoogical order.		X	X	X	
Section G - Competitive exercise reports					
File of all competitive exercise reports..		X	X	X	
Section H - List of test equipment					
A list of test equipment grouped by type and listed by title, mark, mod, and serial number	X	X	X	X	
Section J - Ship Configuration and Logistics Support Information System (SCLSIS)					
Subsystems and equipment portion of current SCLSIS	X	X	X	X	

Legend

S = Search Radar Subsystem
G = Gun Weapon Subsystem
M = Missile Weapon Subsystem
U = Underwater Weapon Subsystem
N = Navigation Subsystem

individually. The averages are compared and the gun is adjusted to the director if the error is out of tolerance.

Each time this is accomplished, the results of the verification, as well as any adjustments, are recorded in the **combat systems smooth log.**

COMBAT SYSTEMS SMOOTH LOG

Upon completion of the initial, or a subsequent, alignment by a shipyard or support activity, an alignment report is submitted to the ship's commanding officer. The data in this report becomes the baseline information in the combat systems smooth log for future system alignment verification. The combat systems smooth log is a perpetual record of all alignment, calibration, and internal ballistic data. The importance of maintaining the smooth log cannot be overemphasized. A general outline of data that should be included in the smooth log is provided in table 11-1. Reproducible forms for use in the combat systems smooth log may be found in the back of SW225-AO-MMA-010/OP762.

The combat systems smooth log, section J, contains weapon system configuration data from the Ship Configuration and Logistics Support Information System (SCLSIS) manual for your ship. The central SCLSIS database contains the configuration information related to each unit's installed and planned equipment hardware. It identifies the proper level of logistics support required to maintain each piece of equipment. Through the SCLSIS process, configuration data is passed to the Weapon Systems File (WSF) at SPCC, which is used to determine spare parts requirements for ships. The onboard availability of spare parts is critical to keeping your systems up and operational. Therefore, you should always ensure that this section is 100 percent accurate. For more information on SCLSIS and SCLSIS reporting, see NAVSEA Technical Specification 9090-700A, SO752-AA-SPN-010.

SUMMARY

In this chapter we have discussed the fundamental principles of combat systems alignment and alignment verification. First we described how system alignment is established, either during construction or in a shipyard. We then described the common procedures used by fleet personnel to maintain or verify that alignment. Finally, we described the combat systems smooth log. Refer to SW225-AO-MMA-010/OP762 ALIGNTHEORY and the appropriate volume of the SW225-XX-CSA-010 series of publications pertaining to your ship type for further information on combat systems alignment procedures.

REFERENCES

Technical Manual for Theory of Combat Systems Alignment, SW225-AO-MMA-010/OP762 ALIGNTHEORY, Naval Sea Systems Command, Washington, D.C., 1987.

Ship Configuration and Logistics Support System, SO752-AA-SPN-010, Naval Sea Systems Command, Washington, D.C., 1988.

CHAPTER 12

AVIATION ORDNANCE

Aviation ordnance includes bombs, rockets, guided missiles, and guns. In this chapter we will briefly describe each of these types of ordnance. Some Navy aircraft are also capable of delivering mines and conducting antisubmarine warfare (ASW) operations, including the delivery of underwater ordnance. Mines, as well as other underwater ordnance, are covered in chapter 14.

Aviation ordnance has many of the same basic components and characteristics as the gun and missile ordnance described in chapters 4 and 6, respectively. While not identical, bombs and rocket warheads compare closely to gun ammunition in their general make-up, as well as in the types of fuzes they employ. Air-launched missiles, however, differ (if at all) only in size and name from the surface-launched missiles described in chapter 6. As we describe each type of aviation ordnance, some of these similarities and differences will be discussed.

AIRCRAFT BOMBS

Aircraft bomb ammunition comes in many sizes and configurations. These can be easily generalized into four basic types: general-purpose bombs, laser-guided bombs, fire bombs, and bomb clusters. Bombs, unlike Navy gun ammunition, are generally shipped without a fuze. Depending upon the desired effect, different fuze types can be installed. As you will see, general-purpose aircraft bombs can be configured to perform a variety of functions simply by changing the fuze or adding a simple kit. We will briefly describe the different types of bomb fuzes and modification kits in this section.

GENERAL-PURPOSE BOMBS

Low-drag, general-purpose (LDGP) bombs are used in most bombing operations. Their cases (bomb body) are aerodynamically designed (low-drag) and thermally insulated to be carried outside the aircraft. They are released over enemy targets to fall on a ballistic (unguided) trajectory to the point of impact or detonation. The general-purpose bombs currently in use are the LDGP Mk 80 (series). Specifications for the individual bombs are listed in table 12-1.

General-purpose bombs are all configured basically the same, varying only in size and weight.

Table 12-1.—Specifications for general-purpose bombs

	Mk 82	Mk 83	Mk 84
Weight class			
(pounds)	500	1,000	2,000
(kilograms)	226.8	453.5	907.0
Assembled weight			
(pounds)	531	985	1,970
(kilograms)	240.8	446.7	893.4
Filler weight			
(pounds)	192	445	945
(kilograms)	80.1	201.8	428.6

Figure 12-1 illustrates the general make-up of the Mk 80 (series) bombs. The bomb body is designed with internally threaded wells for the installation of suspension lugs (2), a forward fuze, and an after fuze. The bomb also contains a fuze charging receptacle for the bomb to be plugged into the aircraft's electrical bomb arming circuits. The bomb is internally wired to the fuze wells. The bomb may be fitted with either mechanically or electrically armed fuzes.

General-purpose bombs are fitted with fins to provide stability, allowing the bomb to fall in a smooth, definite curve to the target, instead of tumbling. Bomb fins come in two general types—conical and snakeye. The conical fin (fig. 12-2) is used for unretarded mode of delivery. The snakeye fin can be used for either unretarded or retarded mode of delivery. Retarded mode of delivery slows the descent rate of the bomb through the use of air drag plates (fig. 12-3). This allows the delivery of bombs at low altitudes without the danger of aircraft damage from bomb blast or fragmentation. Snakeye fins are used only on the Mk 82 and Mk 83 LDGP, 500 and 1,000 pound bombs. Bombs equipped with Snakeye fins can be attached to the aircraft in such a configuration that the pilot is able to select, in-flight, to release the bombs in either the retarded or unretarded mode. This configuration is normally used.

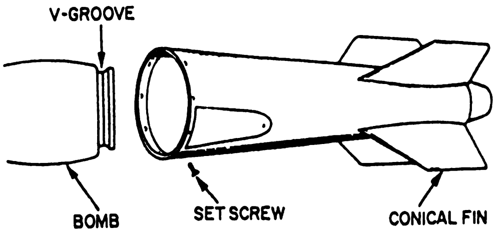


Figure 12-2.—Conical fin assembly.

LASER-GUIDED BOMBS

Laser-guided bombs (LGBs) are Mk 80 (series) LDGP bombs, modified to detect a target illuminated by a laser beam. The modification kit

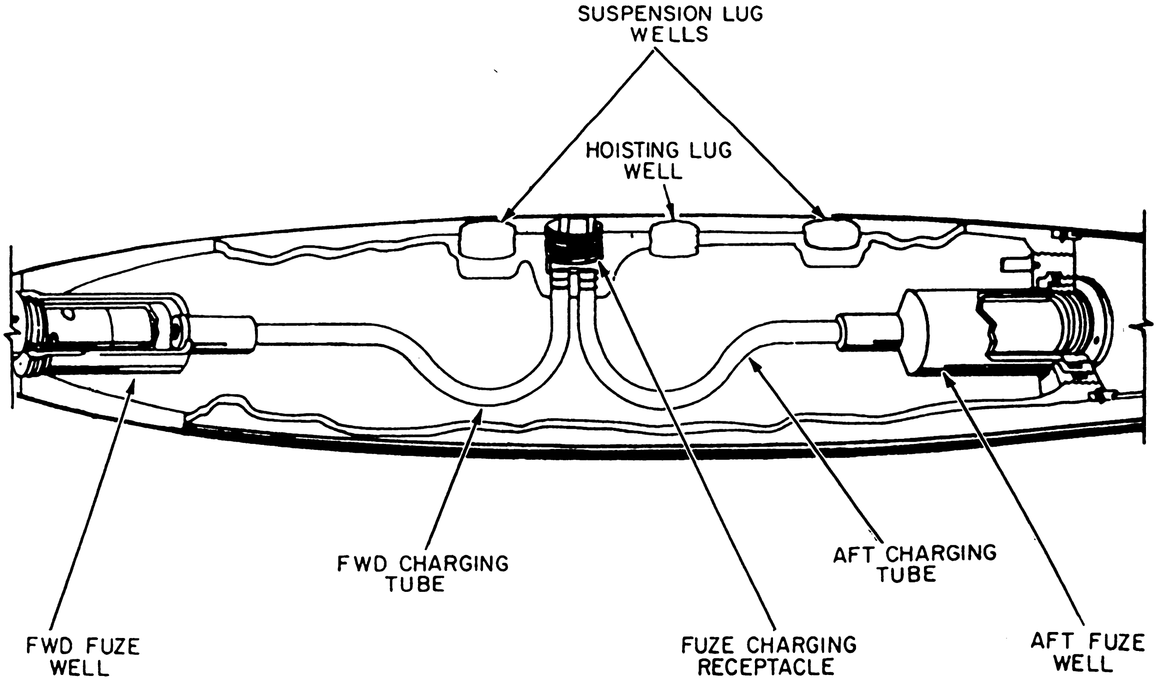


Figure 12-1.—Sectional view of typical LDGP bomb Mk 80 (series).

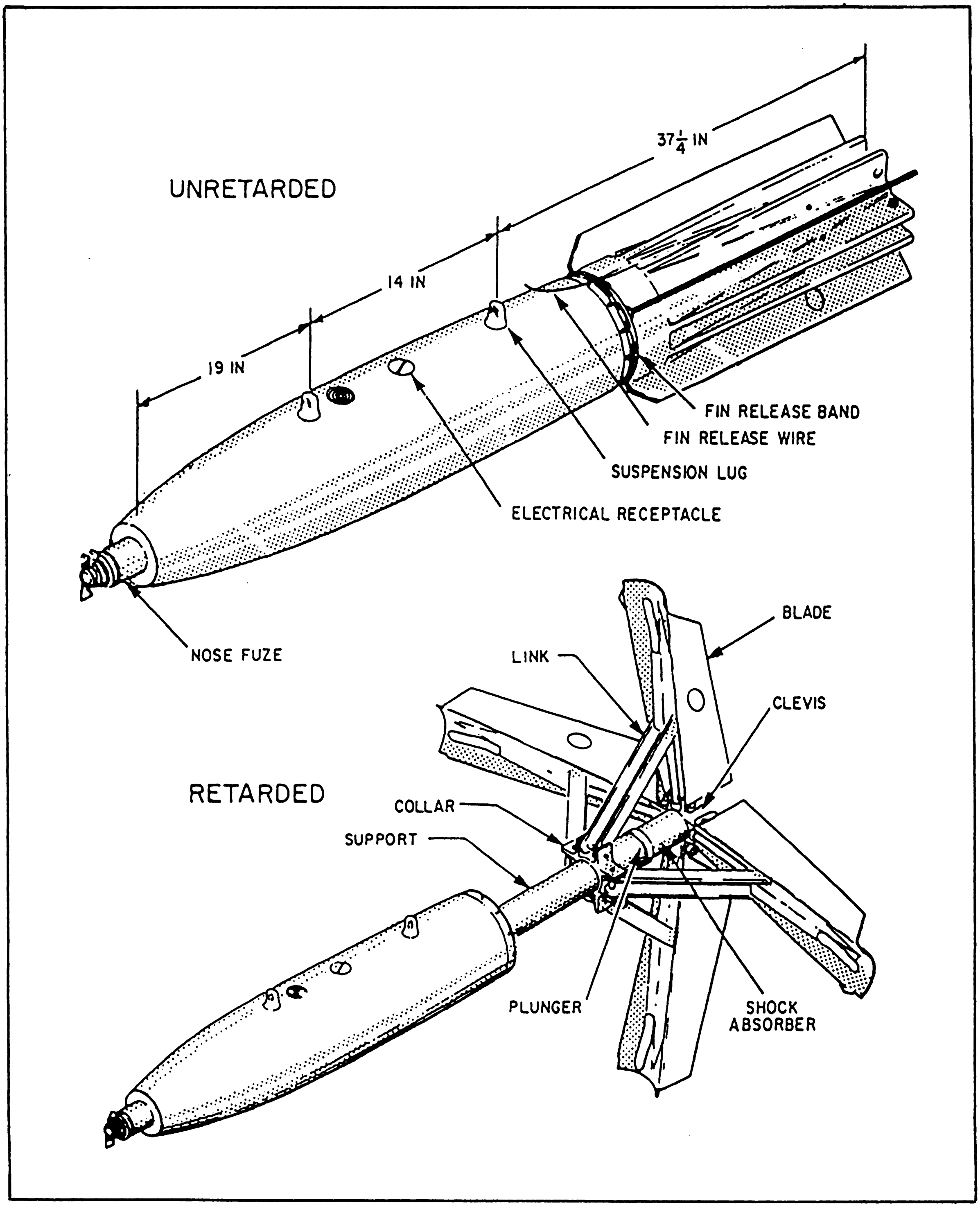


Figure 12-3.—Snakeye fin assembly.

(fig. 12-4) includes a computer-control group (CCG), guidance fins, and a wing assembly. The CCG detects the laser-illuminated target and provides guidance signals to the movable fins. The fins are attached to the CCG. The wing assembly is attached to the aft end of the bomb body to add aerodynamic stability and lift for in-flight maneuvering.

The function of a laser-guided bomb is the same as that of the passive homing missiles described in chapter 6. The obvious difference is that the LGB has no propulsion system.

During the war to liberate Kuwait in 1991, laser-guided bombs were used with great success against hardened targets. The great accuracy of these weapons allowed them to be delivered so as to hit the weakest point of a target. Hardened bunkers were actually destroyed by LGBs dropped through entrances and roof ventilation ducts.

FIRE BOMBS

A fire bomb is a thin-skinned container of fuel gel designed for use against dug-in troops, supply installations, and land convoys. Fire bombs rupture on impact and spread burning gel on surrounding objects. The Navy also has another type of fire bomb called a fuel-air explosive (FAE) bomb. FAE bombs, instead of spreading gel, produce a cloud of fuel vapor in the air, which is detonated producing both blast and fire damage.

Figure 12-5 illustrates a Mk 77 fire bomb. The Mk 77 bomb holds approximately 75 gallons of fuel gel and weighs about 500 pounds when full. Notice that the container is not equipped with fins. These bombs are intended to tumble end over end when released which tends to spread the gel over a larger area.

FAE bombs are delivered in bomb clusters containing three bombs each. Bomb clusters are described in the following section.

BOMB CLUSTERS

A bomb cluster consists of a dispenser shell filled with small bombs or bomblets. The bomb cluster is loaded on the aircraft as a single unit and released over the target. Once released, its fuze functions at the desired time, initiating the breakopen of the dispenser shell to disperse the bombs/bomblets over the target area. There are three types of bombs/bomblets used in bomb clusters, FAE bombs, antitank bombs, and multipurpose bomblets.

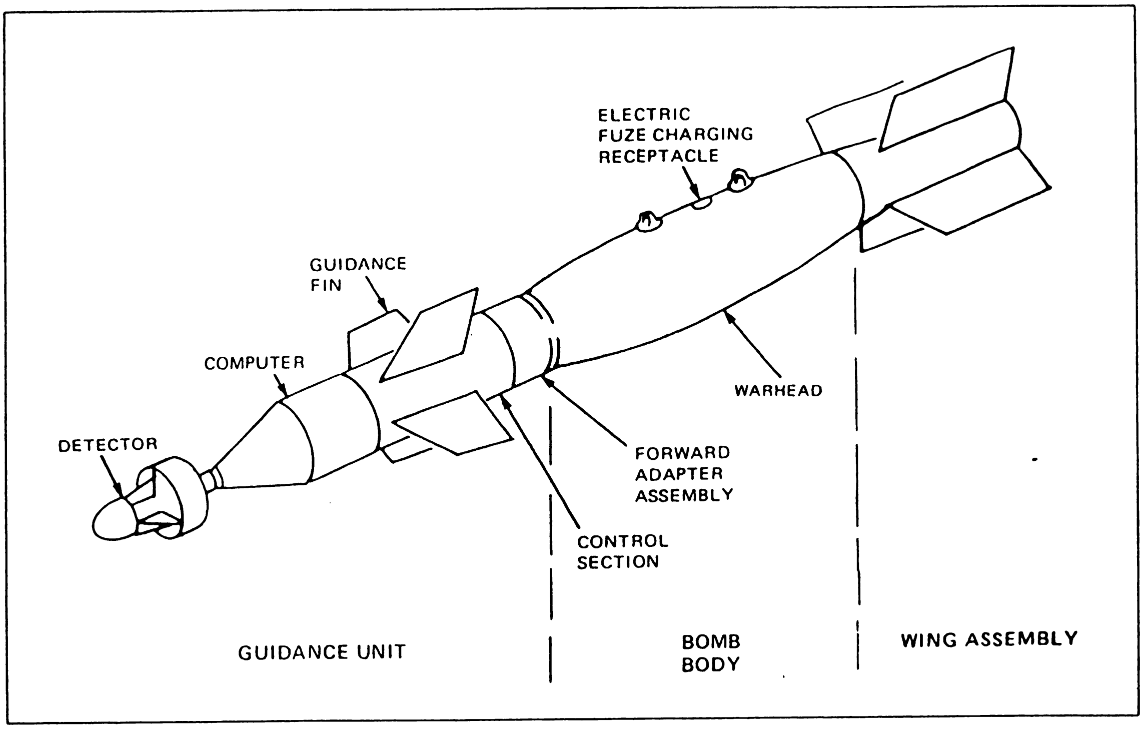


Figure 12-4.—Typical laser-guided bomb.

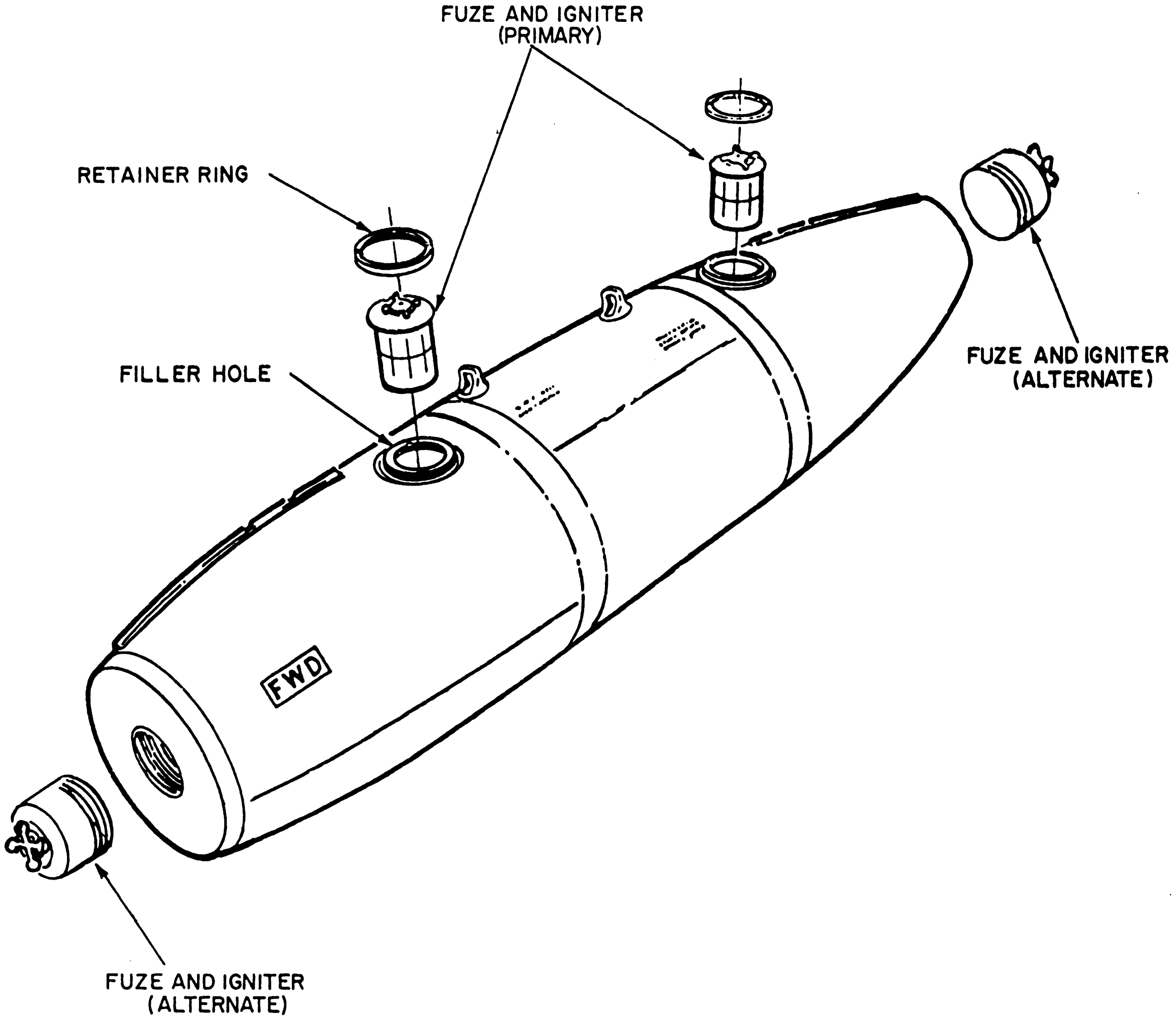

FUZE AND IGNITER (PRIMARY)
RETAINER RING
FILLER HOLE
FWD
FUZE AND IGNITER (ALTERNATE)
FUZE AND IGNITER (ALTERNATE)

Figure 12-5.—The Mk 77 fire bomb.

BOMB FUZES AND KITS

Bomb detonation is controlled by the action of a fuze. A bomb fuze can be an electrical or mechanical device. Some of the terminology associated with bomb fuzes includes:

1. Arming time. The time between bomb release and when the bomb is fully armed.
2. Functioning time. The time required for a fuze to detonate after impact or a preset time.
3. Delay. When the functioning time of a fuze is longer than 0.0005 second.
4. Instantaneous. When the functioning time of a fuze is 0.0003 second or less.
5. Nondelay. When the functioning time of a fuze is 0.0003 to 0.0005 second.
6. Safe air travel. The distance along the trajectory that a bomb travels from the releasing aircraft in an unarmed condition.

Mechanical Fuzes

In its simplest form, a mechanical fuze is like the hammer and primer used to fire a rifle cartridge. A mechanical force (the bomb impacting the target) drives a striker into the sensitive detonator. As with gun projectile fuzes, bomb fuzes require certain safety features to make them safe to handle and stow. As you will recall, gun projectile fuzes are armed using the forces of inertia: setback, creep, centrifugal, and impact. Bombs, however, are not subjected to these forces in a magnitude sufficient to be usable. They are not fired from a rifled gun barrel that would subject them to a rapid acceleration or cause them to spin. They are subjected to impact, but it is obvious that the bomb should be armed prior to this. Figure 12-6 illustrates an M904 (series) mechanical impact fuze. The arming vane is actually a rotating propeller configured with a shaft that is geared to the arming mechanism. When the bomb is loaded onto the aircraft, the arming vane is pinned in place by the arming wire that is attached to the aircraft. When the bomb is released, the arming wire is pulled from the guide hole, allowing the arming vane to spin freely. As the bomb descends, airflow across the arming vane rotates it to arm the bomb fuze. The arming vane must rotate a certain number of revolutions, which translates to the desired safe air travel distance to arm the bomb.

Electrical Fuzes

Electric fuzes require an electric pulse from the aircraft fuze function control (FFC) system. The FFC gives in-flight selection of function delay and arming time delay times. The Navy presently uses the Mk 344 and Mk 376 electric fuzes (fig. 12-7). These fuzes are used in conjunction with mechanical nose fuzes and with the Mk 43 target-detecting fuze.

The Mk 43 target-detecting nose fuze (fig. 12-8) is a proximity variable time (VT) fuze that gives airburst capability for electric fuzed Mk 80

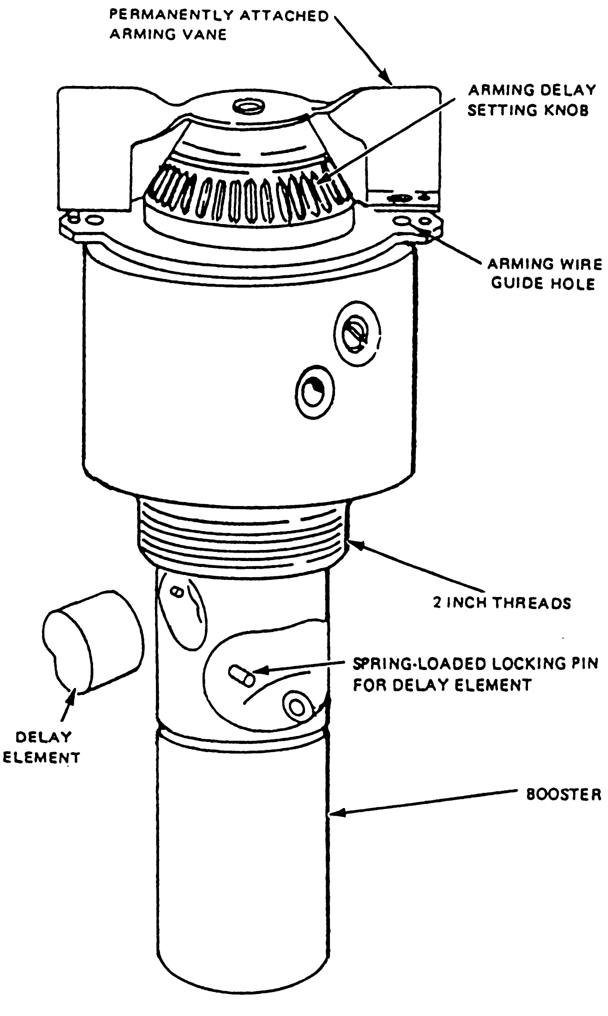

PERMANENTLY ATTACHED ARMING VANE
ARMING DELAY SETTING KNOB
ARMING WIRE GUIDE HOLE
2 INCH THREADS
SPRING-LOADED LOCKING PIN FOR DELAY ELEMENT
DELAY ELEMENT
BOOSTER

Figure 12-6.—Mechanical impact nose fuze M904 (series).

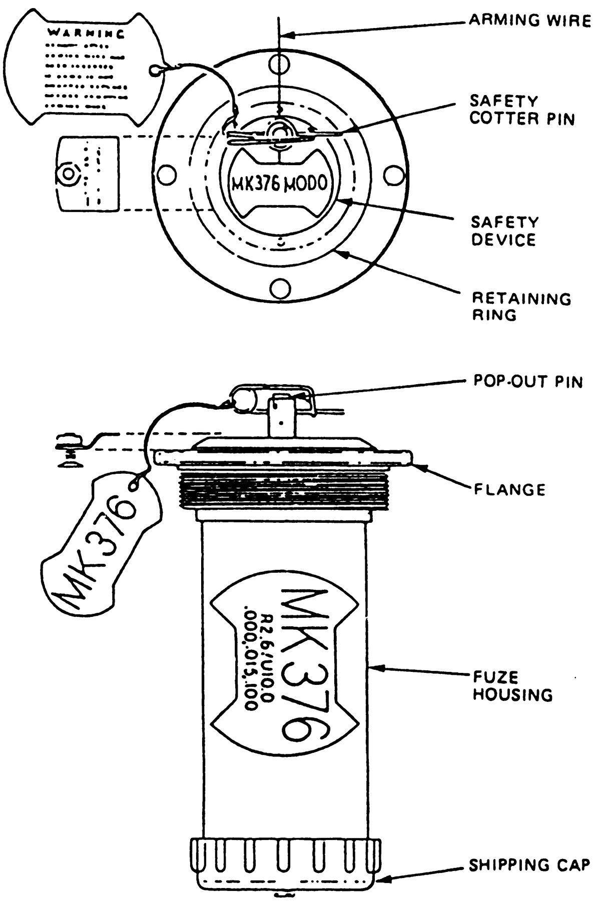


Figure 12-7.—Electric fuze.

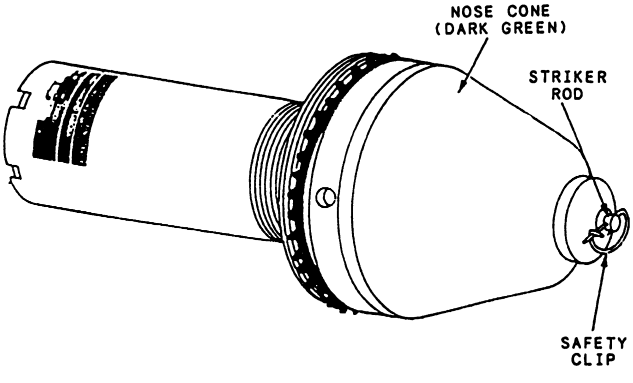


Figure 12-8.—Mk 43 VT nose fuze.

(series) bombs. These VT bomb fuzes operate much like the projectile VT fuzes previously described.

Destructor Kit

A general-purpose bomb can be converted to an air-laid destructor mine (DST) with the addition of a modification kit. These mines can be fitted with three types of fuzes—acoustic, pressure, and magnetic. Destructor mines lay on the bottom and are therefore effective only in relatively shallow water.

AIRCRAFT ROCKETS

The rocket is an ancient device. Its first use as a weapon was by the Chinese against the invading Mongols more than 700 years ago. Its first successful use as an air-launched weapon was in August of 1944. The aircraft rocket has since proved to be a versatile and highly effective weapon against targets that were previously difficult or impossible to hit with bombs or artillery.

The rocket can be delivered to any target within combat range of the carrying aircraft and can be fired from a great variety of angles and altitudes. This was especially effective in the Korean war, where rockets were fired from low-flying aircraft into caves, earth-covered revetments, and railroad tunnels behind enemy lines, destroying large quantities of equipment and supplies that were thought to be safe from aerial bombardment. The Vietnam conflict saw the extensive use of rockets fired from nearly every type of aircraft, including helicopters, propeller-driven, and jet aircraft.

Two types of rockets are currently in use by the Navy. The first is the 2.75-inch (70-mm) folding-fin aircraft rocket (FFAR) which is known as the "Mighty Mouse." The second is the 5.0-inch (127-mm) "Zuni." These two rockets will be described later in this text. We will first describe the general components that make-up an aircraft rocket. Rockets generally consist of a motor and a warhead with fuze.

ROCKET MOTOR

The motor of a rocket (fig. 12-9) consists of those components required to propel and stabilize

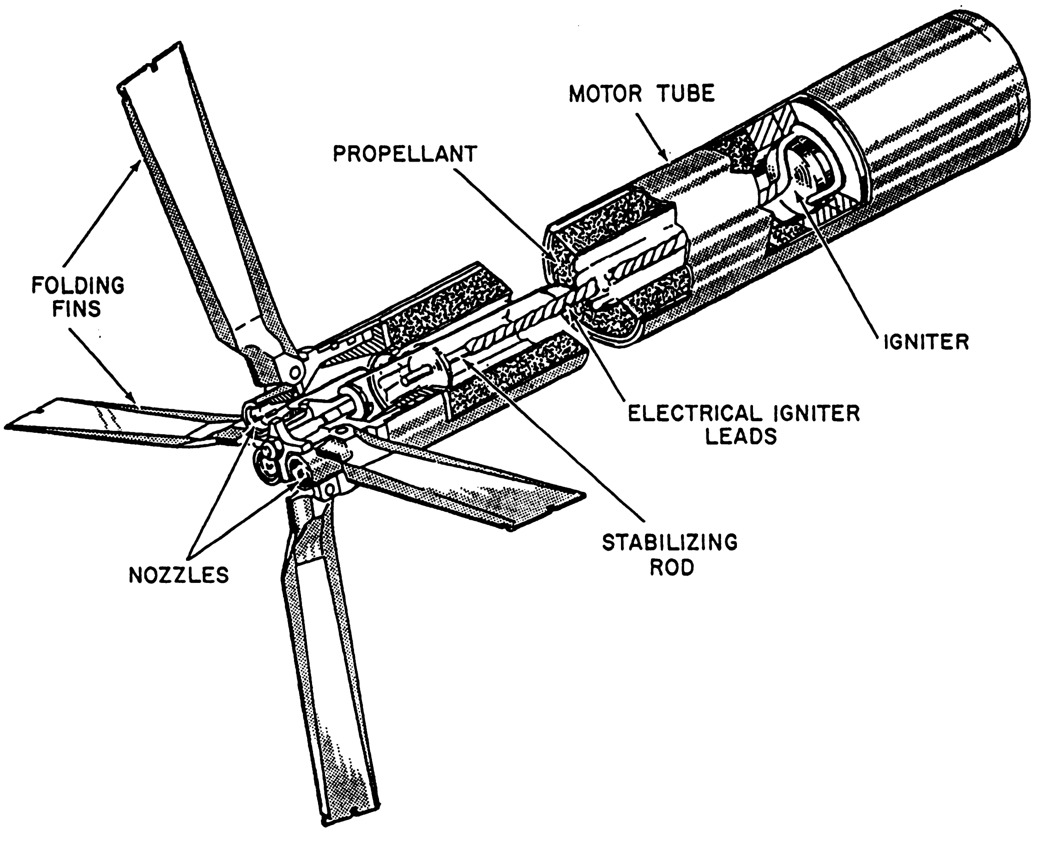


Figure 12-9.—Components of a typical rocket motor.

the rocket in flight. Not all rocket motors are identical, but they do have certain common components. These are the motor tube, propellant, stabilizing rod, igniter, and nozzle and fin assembly. Refer to figure 12-9 as we briefly describe each component.

Motor Tube

The motor tube supports the other components of the rocket. All are presently made of aluminum, threaded internally in the front for warhead installation, and grooved or threaded internally in the rear for nozzle and fin installation.

Propellant

A rocket may be propelled by either liquid or solid fuel. However, only solid fuel propellants are currently used.

Stabilizing Rod

The salt coated stabilizing rod prevents unstable burning of the propellant and reduces flash and after-burning.

Igniter

The igniter is a disc-shaped container of black powder and magnesium, one or two electrical squibs, and lead wires that extend through the wall of the igniter. Firing voltage is supplied to the igniter through a contact disk or band on the motor that touches firing circuit contacts inside the launcher when the rocket is properly loaded.

Nozzle and Fin Assembly

There are several nozzle configurations. Most notable however, is the nozzle types used on rockets designed for launch from helicopters and other low-speed aircraft (LSFFAR). These nozzles are designed to impart a stabilizing spin to the rocket. Rockets fired from high-speed aircraft rely solely on the slant of the fins to impart the stabilizing spin.

There are two basic folding fin designs currently in use—straight and wrap-around. Straight fins fold back behind the rocket extending its length while wrap-around fins are compressed, against spring pressure, into notches in the rocket motor tube. Both expand after firing, once the rocket clears the launcher tube. Both are held in the collapsed position by a retainer. The wrap-around fin retainer is blown off by the thrust of the burning rocket motor, while the straight folding fins are extended by gas pressure from the rocket motor against a piston. The piston moves a crosshead, which operates the fins. Figure 12-10 illustrates the operation of these two types of fin assemblies.

ROCKET WARHEADS

As with all other types of ammunition, rocket warheads come in various types or classes. These classifications include: high-explosive, flechette, smoke, flare, and practice. These warhead classifications are discussed in the following paragraphs.

High-Explosive Warheads

Within the high-explosive warhead category are several types of heads, designed for specific types of targets. These include:

1. HE fragmentation (HE-FRAG)
2. HE antitank (HEAT)
3. HE antitank/antipersonnel (AT/APERS or ATAP)
4. HE general-purpose (GP)

Fragmentation warheads are designed to be effective against personnel and light targets such as trucks and parked aircraft.

The HE antitank (HEAT) warhead can be used effectively against both tanks and fortified positions. This warhead produces a jet of high-velocity, high-temperature particles that can penetrate an extraordinary thickness of armor or concrete. The searing jet penetrates and fills the tank killing the occupants.

The HE antitank/antipersonnel (AT/APERS) warhead combines the effectiveness of the fragmentation and antitank warheads.

The general-purpose (GP) type of warhead is a compromise between the armor-piercing and the fragmentation designs.

Flechette Warheads

Flechette warheads (fig. 12-11) are designed to be effective against personnel and lightly

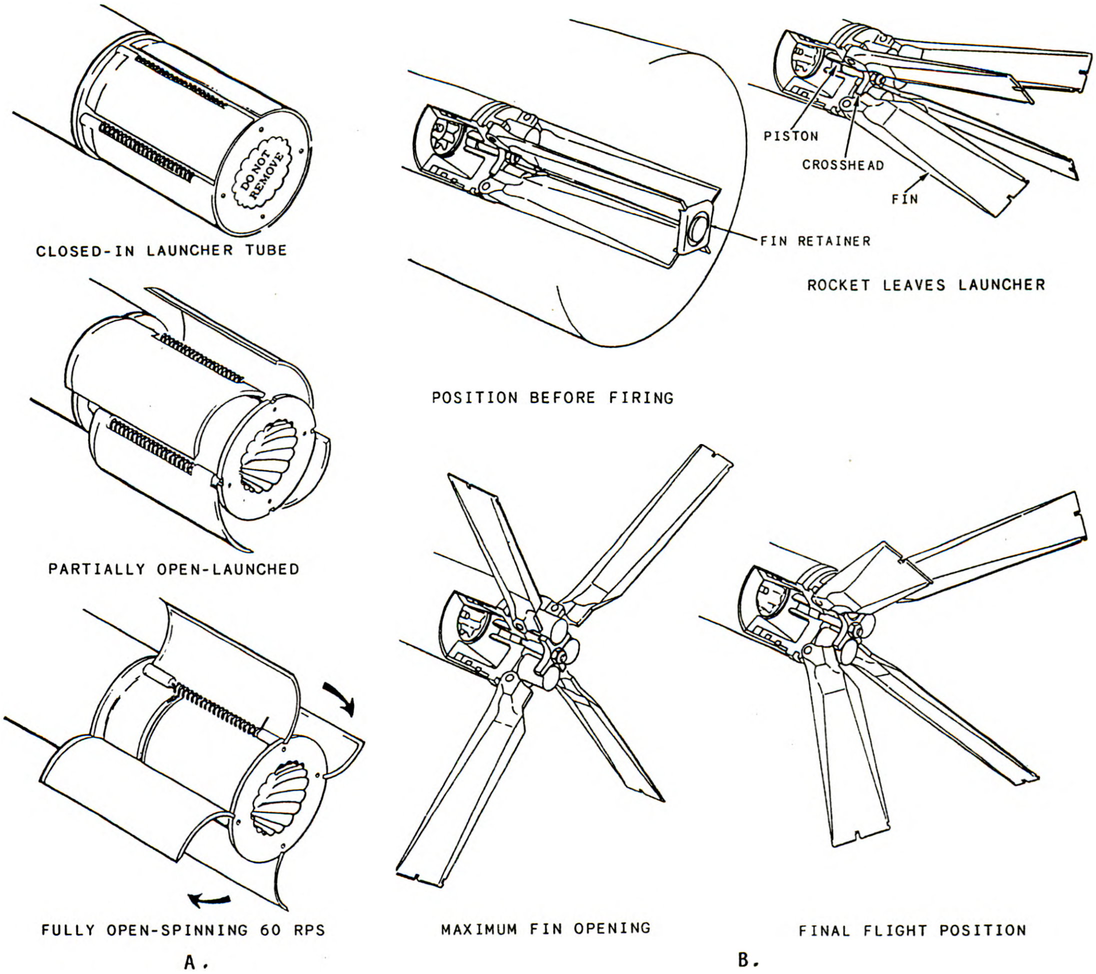


Figure 12-10.—A. Wrap-around fin operation. B. Straight folding fin operation.

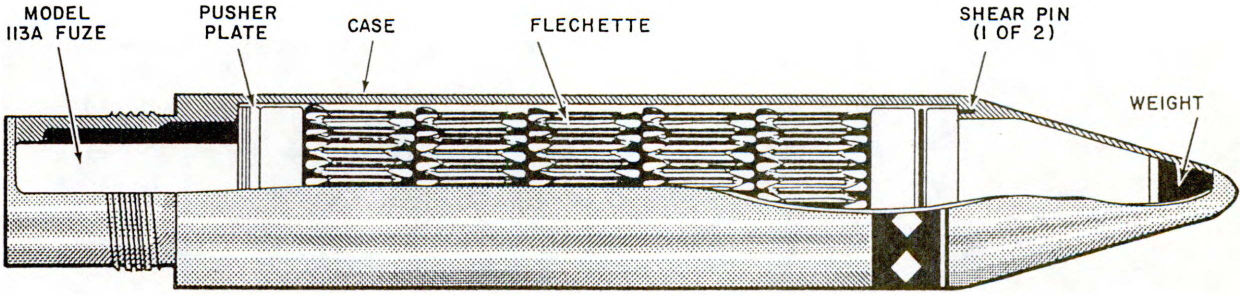


Figure 12-11.—Flechette warhead.

armored targets. These warheads contain a large number of small arrow-shaped projectiles. A small explosive charge in the base fuze of the warhead dispenses the flechettes through the nose of the warhead after rocket motor burnout. Target damage is caused by impact of the high velocity flechettes.

Smoke Warheads

Smoke warheads are designed to produce a volume of heavy smoke for target marking or the masking of troop movements. Smoke warheads use white phosphorus (WP) or plasticized white phosphorus (PWP) as a smoke-producing agent.

Flare Warheads

Flare warheads (fig. 12-12) are designed to provide illumination for tactical operations. These warheads consist of a delay action fuze, an illuminating candle, and a parachute assembly. Approximately 15 seconds after the rocket is fired, the fuze simultaneously ignites the expelling charge and the candle ignition composition. The expelling charge generates gas pressure, which separates the flare and parachute from the outer case. This deploys the parachute to suspend the burning flare.

Practice Warheads

Practice warheads are designed to simulate both the weight and ballistic characteristics of the high-explosive service warheads. The practice warhead is painted blue.

ROCKET WARHEAD FUZES

Rocket fuzes are primarily classified according to their location in the warhead; that is, nose or base fuze. They may be further classified by mode of operation such as, impact, mechanical time,

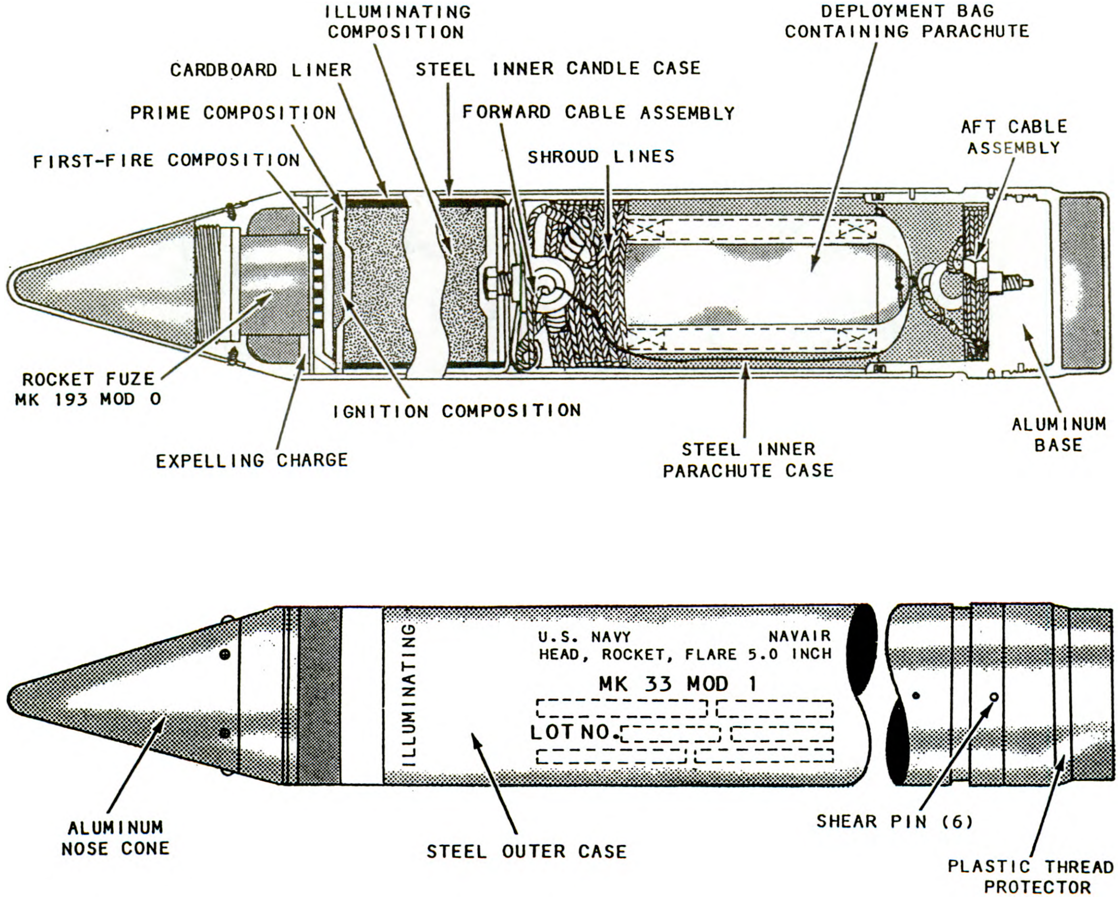


Figure 12-12.—Flare warhead.

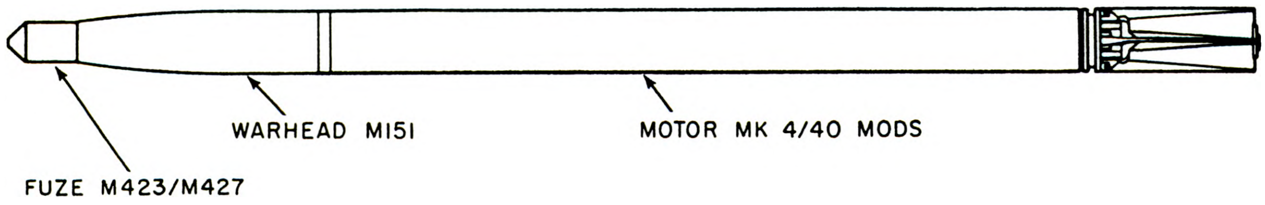


Figure 12-13.—2.75-inch FFAR/LSFFAR.

or proximity. These fuzes function the same as those described in chapter 4. Refer to chapter 4 to review these descriptions.

2.75-INCH ROCKET

The 2.75-inch "Mighty Mouse" airborne rocket (fig. 12-13) has proved to be an effective air-to-ground weapon against most any target. It is carried and launched from both 7- or 19-round packages, called pods (fig. 12-14), and fired in large numbers to produce a shotgun pattern. Rockets designed for low-speed firing (LSFFAR) however, may only be fired singly.

5.0-INCH ROCKET

Like the 2.75-inch rocket, the 5.0-inch "Zuni" rocket is carried and launched from a multiple tube launcher. However, due to their larger size, Zuni pods come only in 2- and 4-round configurations. Though larger, they are similar in appearance to the 2.75-inch rocket.

AIRCRAFT GUIDED MISSILES

Air-launched guided missiles contain the same basic components and function in the same manner as the surface-launched missiles described in chapter 6. Therefore, in this section we will only provide a basic description of the air-launched guided missiles currently in the Navy inventory. It may be helpful, however, to review the guided missile fundamentals section of chapter 6 before proceeding.

All air-launched guided missiles fall into one of two categories—air-to-air or air-to-surface. In the air-to-air category we have:

1. AIM-7 Sparrow III
2. AIM-9 Sidewinder
3. AIM-54 Phoenix

The air-to-surface category includes:

1. AGM-65 Maverick
2. AGM-78 Standard Anti Radiation Missile (ARM)
3. AGM-45 Shrike
4. AGM-88 HARM
5. AGM-84 Harpoon

Air-launched missiles are launched from either a rail or an ejector style launcher. The rail functions the same as those described on surface ship launchers. The ejector launcher, however, functions to release the missile, in some cases using a small explosive charge to eject the missile from the launcher as it is fired.

AIR-TO-AIR MISSILES

Air-to-air missiles are launched from fighter, and, in some cases, attack (bomber) aircraft to intercept and destroy enemy aircraft.

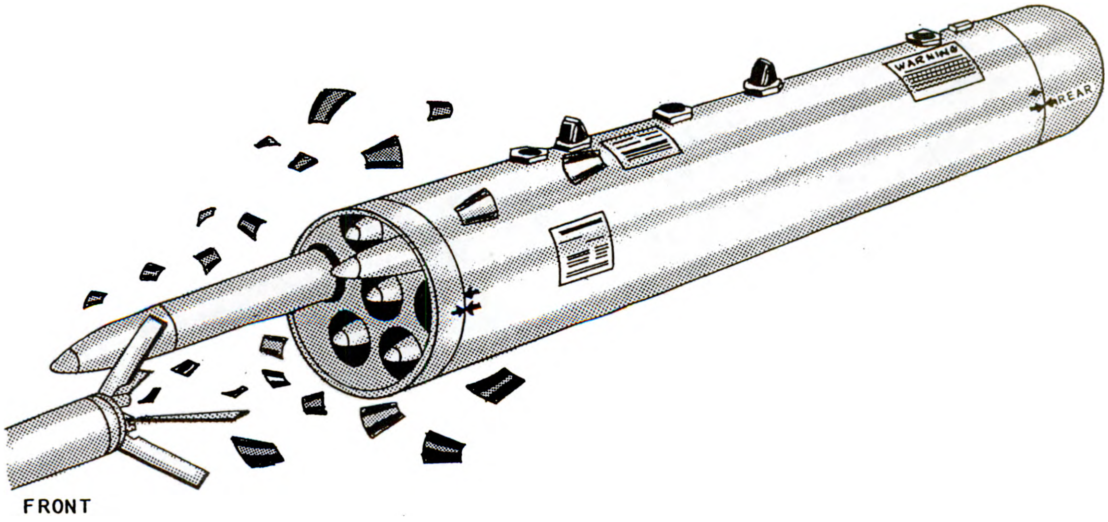


Figure 12-14.—2.75-inch FFAR 7-round launcher.

AIM-7 Sparrow III

The AIM-7 Sparrow III (fig. 12-15) is a supersonic air-to-air DTRM guided missile. It is designed to be either rail- or ejection-launched from the F-4, F-14, and F/A-18 aircraft. The Sparrow III is a semiactive missile which depends on RF energy from the launching aircraft, reflected off the target, for guidance.

It must be noted here that the Sparrow missile is also employed aboard surface ships for close-in antiair defense. The surface ship variation, called NATO Sea Sparrow, is launched from a movable box-type launcher.

AIM-9 Sidewinder

The AIM-9 Sidewinder (fig. 12-16) is a supersonic, air-to-air missile used to intercept and destroy enemy aircraft at relatively short ranges. The Sidewinder uses a passive infrared guidance system to detect and home on the hot exhaust of the target. The Sidewinder can be launched from the A-6, A-7, F-4, F-14, and F/A-18 aircraft.

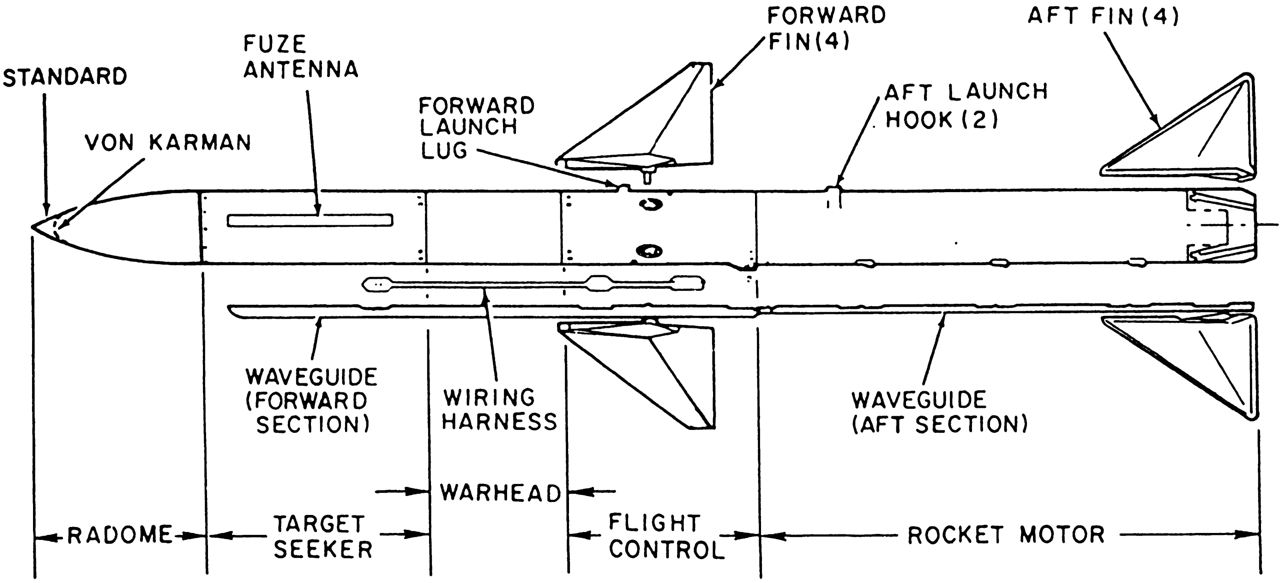


Figure 12-15.—AIM-7 Sparrow III guided missile.

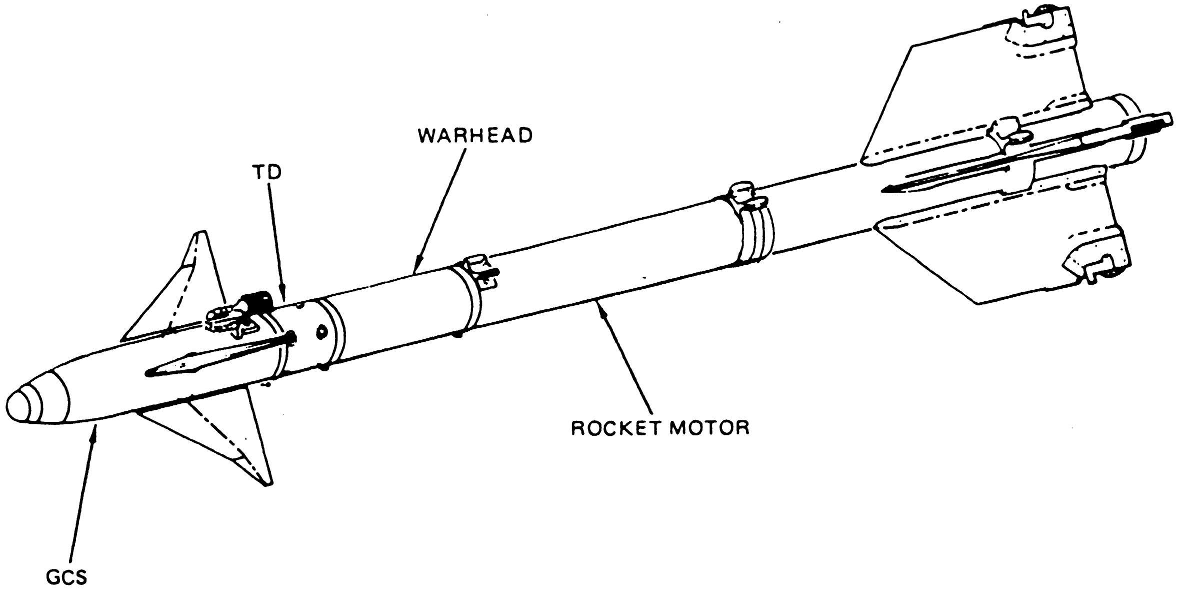


Figure 12-16.—AIM-9 Sidewinder guided missile.

AIM-54 Phoenix

The tactical AIM-54 Phoenix (fig. 12-17) is an air-launched, air-to-air guided missile that employs active, semiactive, and passive homing capabilities. The Phoenix is used as a long-range air-intercept missile, launched from the F-14 aircraft. The F-14 is equipped with the AWG-9 Airborne Missile Control System (AMCS). The system is capable of multiple missile attacks of up to six missiles, supplying simultaneous guidance against widely dispersed targets. In addition, the missile has dogfight, ECCM, and anticruise missile capabilities.

AIR-TO-SURFACE MISSILES

Air-to-surface missiles are designed to destroy a variety of targets. Some are used against enemy radars to suppress their ability to accurately employ antiaircraft defenses, while others are used to destroy tanks, fortified ground installations, and ships.

AGM-65 Maverick

The tactical AGM-65 Maverick (fig. 12-18) is a laser-guided, rocket-propelled, air-to-ground missile. It is used against armored vehicles, fortified ground positions, and surface ships. It,

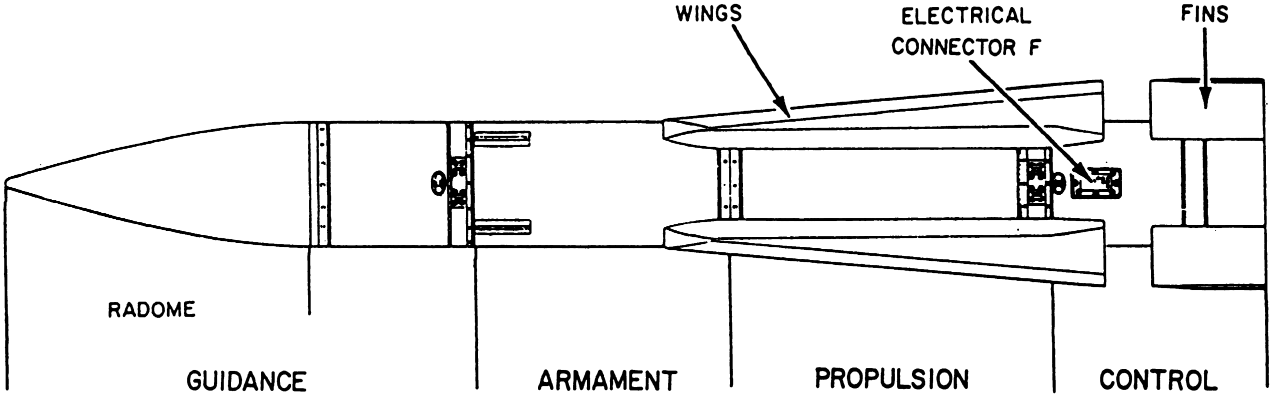
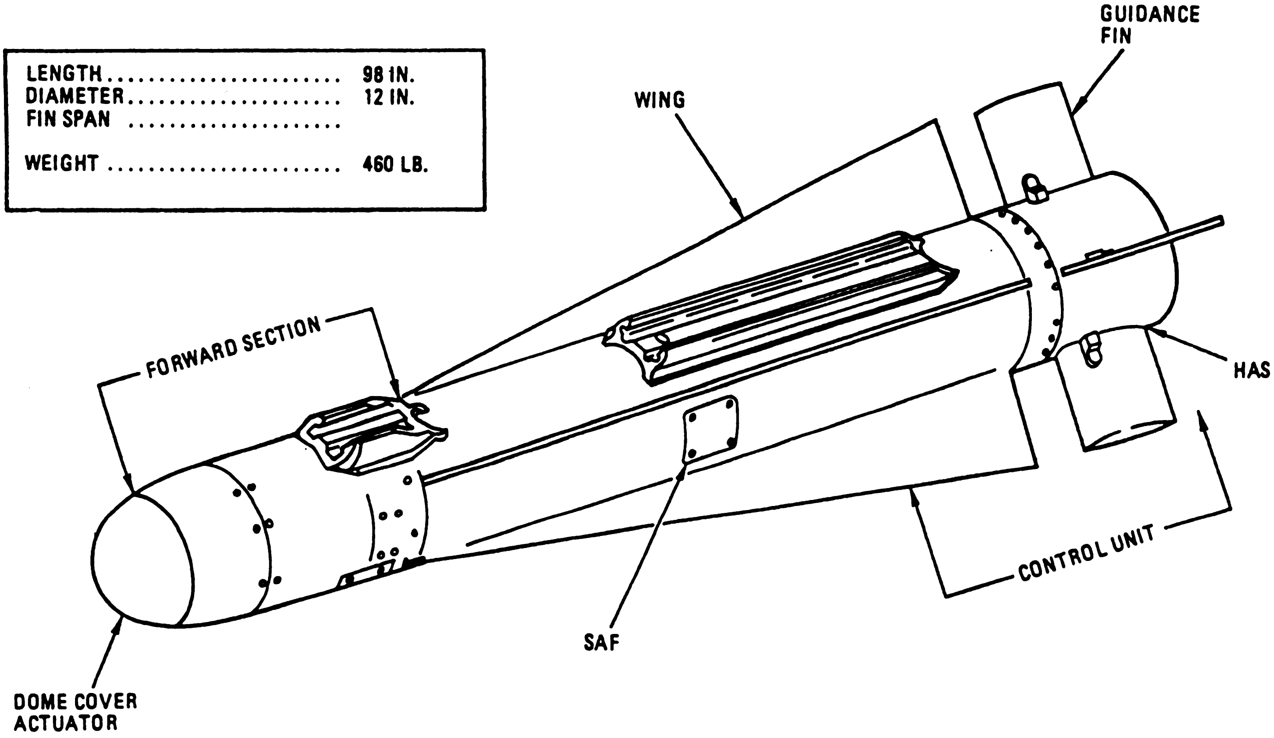


Figure 12-17.—AIM-54 Phoenix guided missile.



LENGTH........................	98 IN.
DIAMETER......................	12 IN.
FIN SPAN	
WEIGHT	460 LB.

Figure 12-18.—AGM-65 Maverick missile.

and its associated system, is compatible with the A-4, A-6, AV-8, and F/A-18 aircraft. The laser designator can be a ground device or mounted on either the launching or other aircraft.

AGM-78 Standard Anti Radiation Missile (ARM)

The Standard ARM (fig. 12-19) is an air-launched, supersonic missile used against targets that radiate microwave electromagnetic energy. It uses a passive homing device to develop guidance information from the energy radiated by the target. The missile is ejection-launched from the A-6 aircraft.

AGM-45 Shrike

The AGM-45 Shrike surface attack guided missile (fig. 12-20) is a passive homing air-to-ground antiradar missile.

AGM-88 HARM

The AGM-88 high-speed antiradiation missile (HARM) (fig. 12-21) offers performance improvements over the existing Standard ARM and Shrike missile for defense suppression and similar operations. The HARM, in conjunction with the launching aircraft's avionics, detects, identifies, and locates enemy radars, displays threat information, and computes target parameters. It can be launched from the A-6, A-7, and F/A-18 aircraft.

Harpoon

The air-launched Harpoon antiship cruise missile is the same basic missile described in chapter 6, but configured for air-launch.

AIRCRAFT GUNS

Currently, the Navy uses only one type of aircraft-mounted gun system, the M61A1 automatic gun. Made by General Electric, the M61A1 automatic gun can be configured for installation aboard A-7, F-14, and F/A-18 aircraft. Due to the complexity of the system, we will provide only a general description of the M61A1 in this text. For more detailed information, refer to *Aviation Ordnanceman 3 & 2*, NAVEDTRA 12308.

M61A1 AUTOMATIC GUN

The M61A1 is a six-barrel, rotary-action automatic gun, based on the machine-gun design of Richard J. Gatling. The gun consists of a

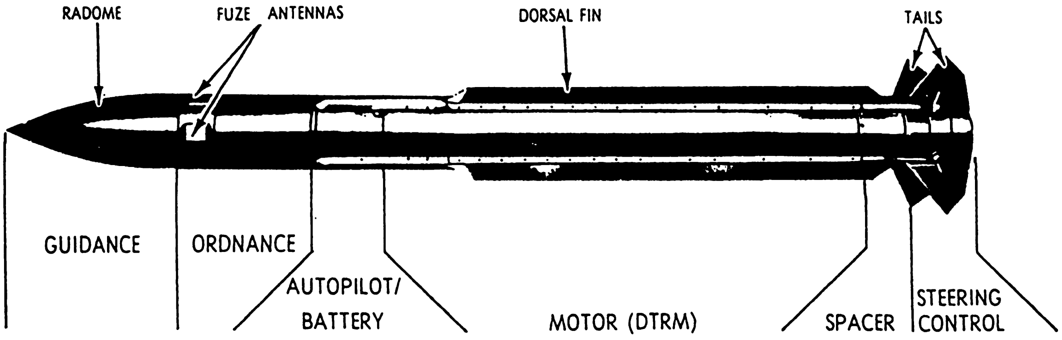


Figure 12-19.—AGM-78 Standard ARM guided missile.

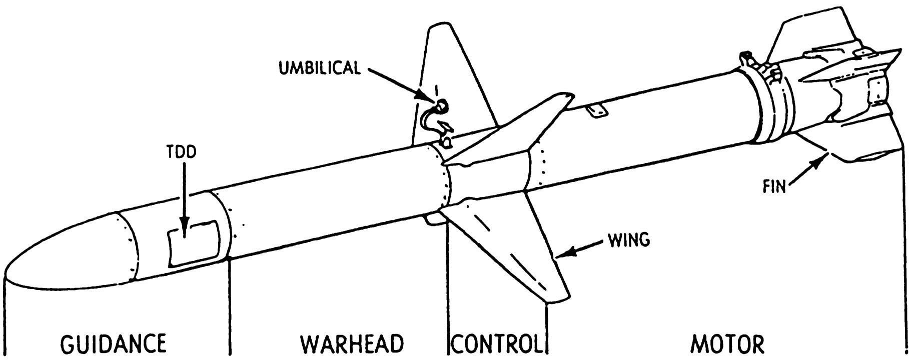


Figure 12-20.—AGM-45 Shrike guided missile.

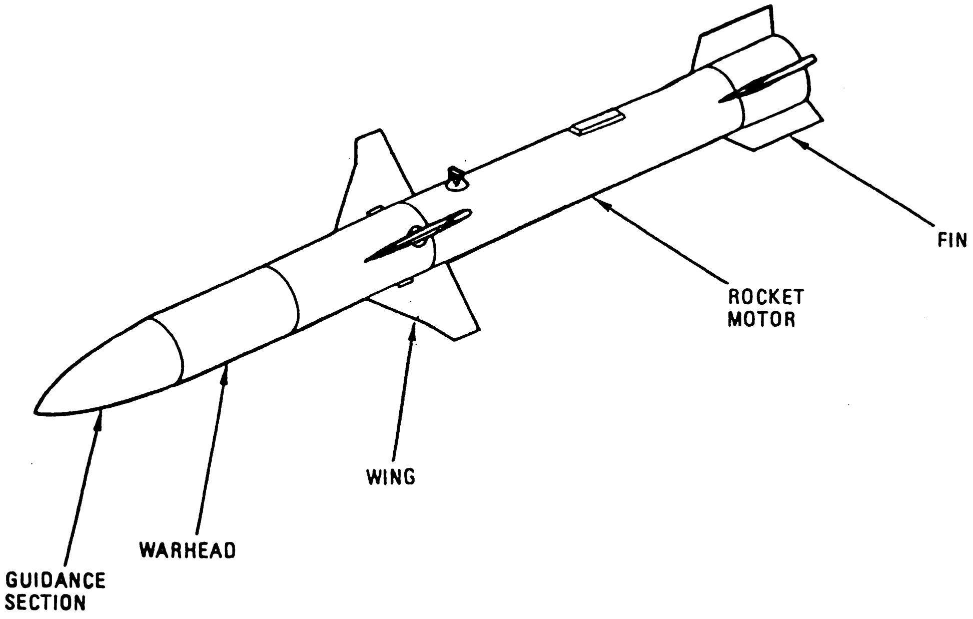


Figure 12-21.—AGM-88 HARM.

revolving cluster of barrels, each barrel being fired once per revolution. The M61A1 is hydraulically driven, electrically controlled, and can fire 4,000 to 7,200 rounds of 20-mm ammunition per minute. The gun has a pilot selectable firing rate of either 4,000 (GUN LOW) or 6,000 (GUN HIGH) rounds per minute. It is designed for either air-to-ground or air-to-air gunnery missions.

Ammunition is supplied to the M61A1 gun by an ammunition handling and storage system that is unique to each type of aircraft. The system uses an endless conveyor that transports 20-mm ammunition from the ammunition drum to the gun, while returning expended cases and unfired rounds back to the ammunition drum. Figure 12-22 illustrates the M61A1 gun

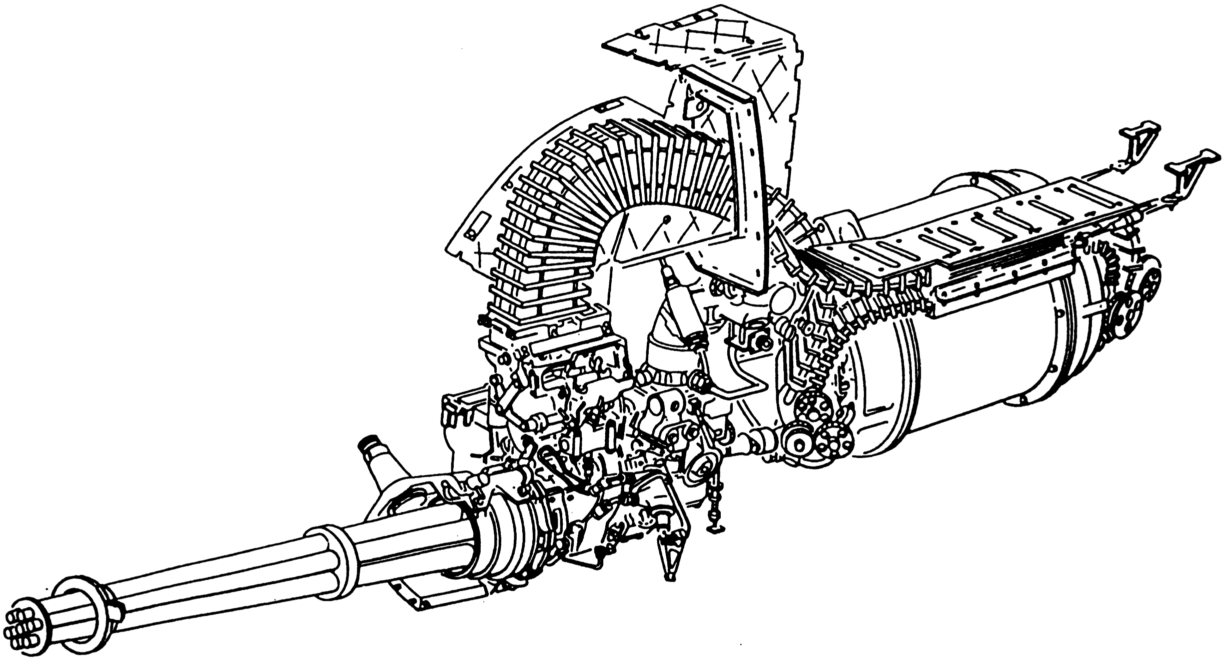


Figure 12-22.—F-14 M61A1 gun installation.

system as configured for installation aboard an F-14.

SUMMARY

In this chapter we have briefly described the different types of ordnance that can be delivered from Navy aircraft. We discussed general-purpose bombs and how they can be configured to meet almost any requirement. We also talked about air-launched rockets and how their special qualities enable our aircraft to engage targets previously denied them. We reviewed the great variety of air-launched guided missiles, both air-to-air and air-to-ground. Finally, we took a quick look at the M61A1 automatic aircraft gun. This chapter is intended to give you a general knowledge of these topics. Refer to *Aviation Ordnanceman 3 & 2*, NAVEDTRA 12308, for in-depth study and more detailed explanations.

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CHAPTER 13

RIVERINE CRAFT AND ARMAMENT

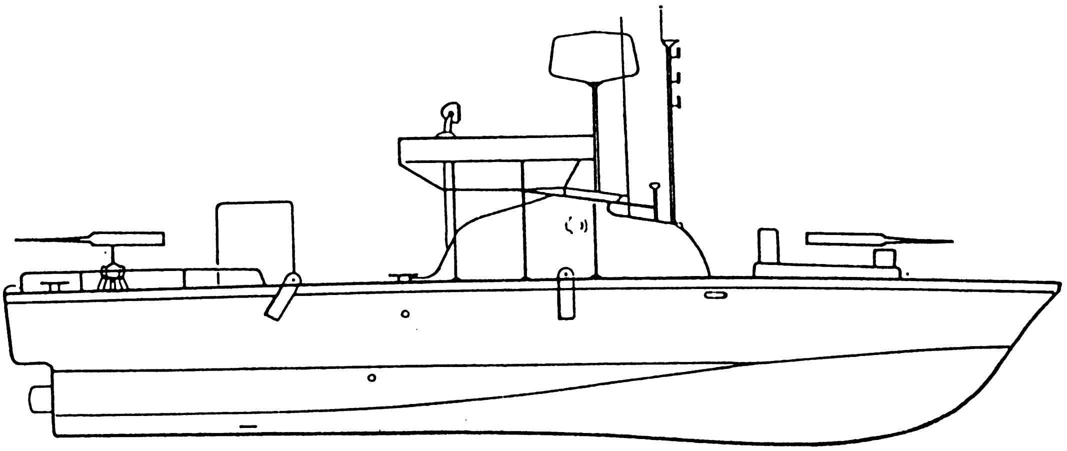
Riverine forces operate in an environment unfamiliar to the average destroyer sailor. They use weapons seen by most of us only in a Rambo movie. In full concept, riverine forces integrate and employ various types of ships, craft, aircraft, weapons, and special warfare forces (Marine Corps and naval) to achieve and maintain control over riverine, coastal, and delta areas. The full scope of possible riverine operations, and the various combinations of equipment that could be employed, is well beyond the scope or intent of this manual. In this chapter we will only address the boats and weapons commonly used by naval riverine forces.

RIVERINE CRAFT

Riverine forces are highly versatile and have a wide variety of equipment available to them. Two craft are common to most riverine warfare units. These are the River Patrol Boat (PBR) Mk 2 and the Mini-Armored Troop Carrier (MATC). Each of these will be briefly discussed.

RIVER PATROL BOAT (PBR) MK 2

The PBR Mk 2 (fig. 13-1) is a shallow-draft, high-speed craft capable of performing all normal



CHARACTERISTICS

- **Length:** 31 feet, 11 inches
- **Beam:** 11 feet, 7 inches
- **Draft:** 2 feet
- **Displacement:** 17,443 pounds (fully loaded)

Figure 13-1.—River patrol boat (PBR) Mk 2.

riverine patrol activities and missions. It has a crew of four, and can be armed with a variety of weapons.

The craft is constructed of fiberglass, with girders, bulkheads, decking flats, and stiffeners constructed of balsa wood and polyurethane cores to provide reserve buoyancy. The stanchions are made of aluminum. It is equipped with two diesel engines—each one powering a water jet pump propulsion system.

The PBR Mk 2 is equipped with two heavy machine gun mounts—one forward and one aft. The forward emplacement is normally equipped with two M2 .50-caliber machine guns, but may be fitted with 7.62-mm or 20-mm machine guns or a 40-mm grenade launcher. The aft machine gun mount may also be fitted with a 40-mm grenade launcher. There are two M-60 machine gun mounts midships (one facing each side of the boat) mounted on top of ballistic shields. A single machine gunner is stationed between the two ballistic shields to operate either machine gun as required. The small arms complement includes two M-79 grenade launchers, three M-16 service rifles, one 12-gauge shotgun, and one .357-caliber Magnum revolver.

The PBR Mk 2 is equipped with two radio transceivers and a coastal navigation radar LN-66. The LN-66 provides relative bearing and distance information about ships, land, bridges, navigation markers, or other objects on the surface of the water, ranging from 20 yards to 36 nautical miles from the boat.

MINI-ARMORED TROOP CARRIER (MATC)

The Mini-Armored Troop Carrier (MATC) (fig. 13-2) is a shallow draft boat used to transport people and equipment into riverine areas. It has a crew of two, and is fitted with seven machine gun mounts that can be used to mount M-60 machine guns, grenade launchers, or a mortar. The crew's personal weapons include one M-16 service rifle, one 12-gauge shotgun, one .357-caliber revolver, and one M-79 grenade launcher.

The MATC is constructed primarily of aluminum, with the crew stations armor plated for protection against small-arms fire. The craft can carry up to 16 troops in full battle dress and 500 pounds of equipment. The MATC is fitted with radio and radar systems similar to those installed on the PBR, and uses a jet propulsion system similar to the PBR's.

While the PBR is primarily a patrol craft, and the MATC is a troop carrier, they are usually found operating together. The PBR provides cover for the slower MATC, which has to nose into the beach to disembark troops and unload equipment.

RIVERINE CRAFT ARMAMENT

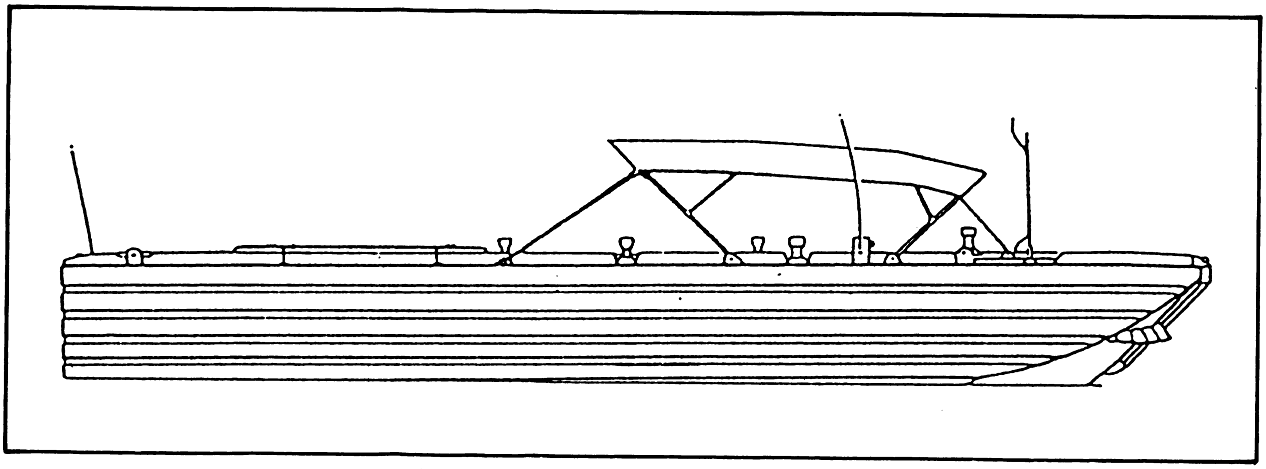
The standard weapons found aboard riverine craft include the .50-caliber M2 machine gun, the 7.62-mm M-60 machine gun, the Mk 4 naval mortar, and the Mk 19 grenade launcher. In this section we will provide a brief description of each of these weapons. The other small-arms mentioned earlier are described in the *Gunner's Mate (Guns)* training manuals.

.50-CALIBER M2 MACHINE GUN

The Browning .50-caliber M2 machine gun (fig. 13-3) is a belt-fed, recoil-operated, air-cooled, crew-served weapon, capable of semiautomatic and automatic fire. With few alterations, the weapon can be fed from either side. Most often though, it is fed from the left side. The one exception to this is when two guns are mounted in the twin forward mount of the PBR. In this configuration, both guns are fed from an ammunition bin between and below the guns; the left gun feeds from the right, and the right gun feeds from the left. The PBR twin mount also uses machine guns modified to be operated electrically using solenoids instead of manual triggers. The electrically operated gun is the M2A1. Refer to FM 23-65 for further information on the Browning .50-caliber M2 MG.

7.62-MM M-60 MACHINE GUN

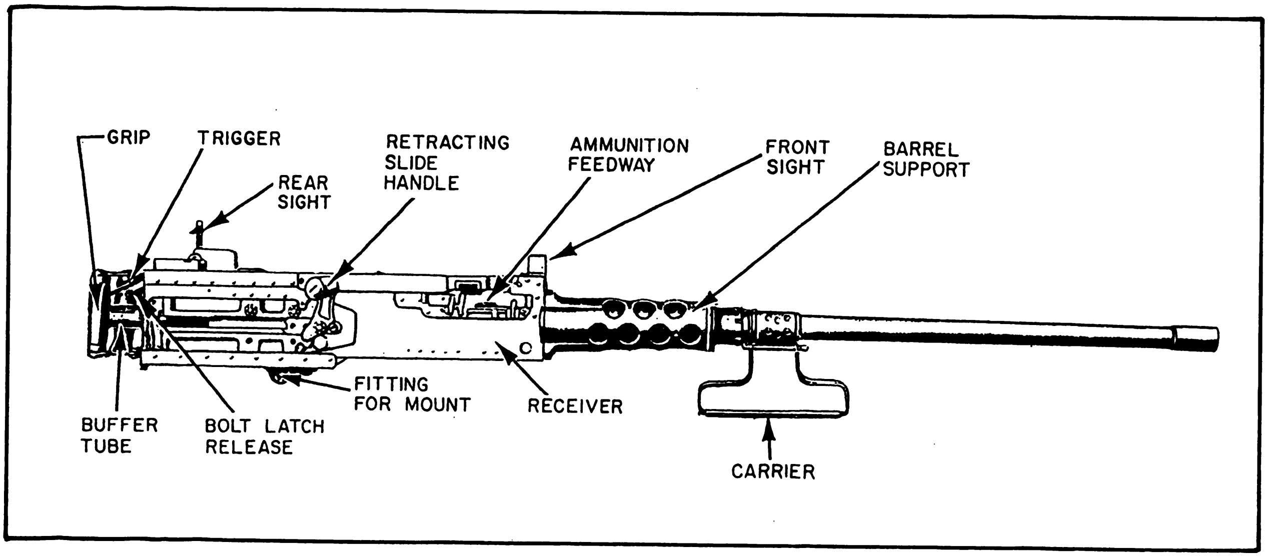
The M-60 machine gun is an air-cooled, belt-fed, gas-operated, automatic weapon. It is used in two versions in the riverine forces—the



CHARACTERISTICS

● **Length:**	**36 feet**
● **Beam:**	**13 feet**
● **Draft:**	**2 feet**
● **Displacement:**	**29,500 pounds (fully loaded)**

Figure 13-2.—The Mini-Armored Troop Carrier (MATC).



CHARACTERISTICS

● **Length:**	**65 inches**
● **Weight:**	**82 pounds**
● **Max. range:**	**7400 yards**
● **Max. effective range:**	**2000 yards**

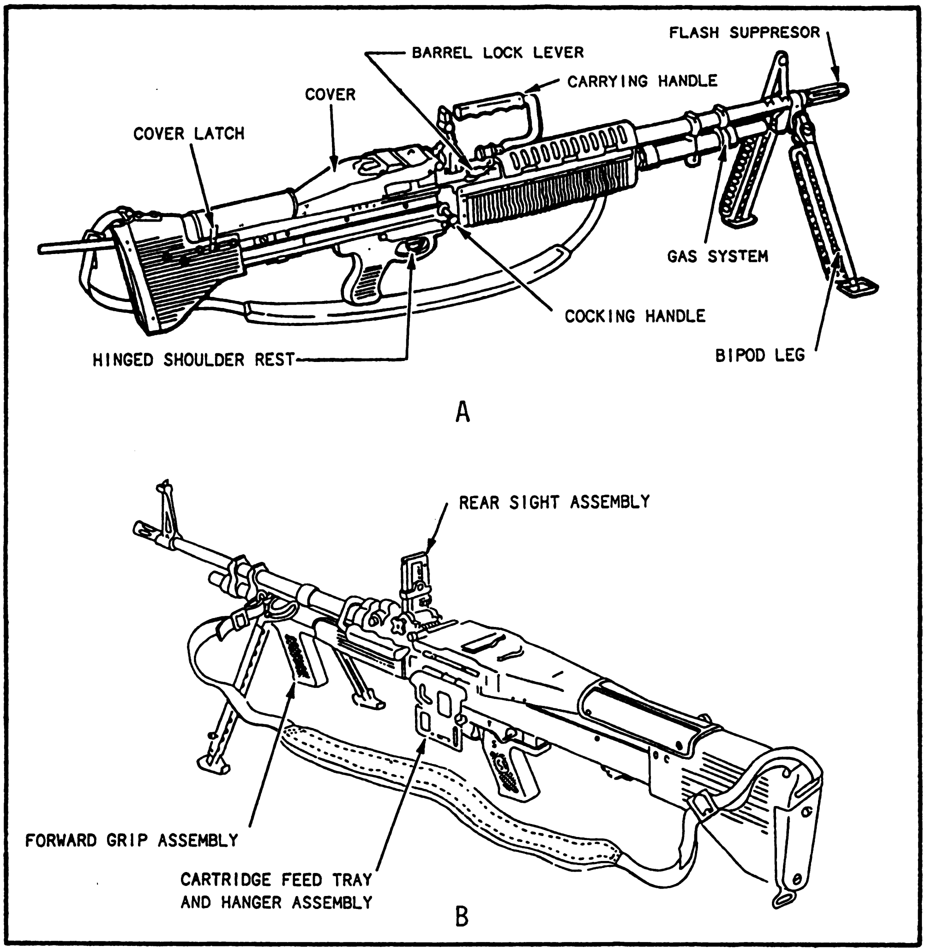
Figure 13-3.—The .50-caliber M2 machine gun.

standard M-60 (fig. 13-4, view A) and the M-60E3 (fig. 13-4, view B). The M-60E3 is lighter in weight than the standard version M-60 and incorporates a forward grip. The lighter weight comes from a shorter barrel and lighter receiver. Both weapons operate the same. For further information on the M-60 MG, see TM 9-1005-213-10; for more detail on the M-60E3, see TM 02705E-10/1.

MK 4 NAVAL MORTAR

The 60-mm Mk 4 naval mortar (fig. 13-5) is designed for mounting on the Mk 16 machine gun tripod stand for installation aboard small craft. It may be drop fired or trigger fired using HE, illumination, or white phosphorus (WP) ammunition. The Mk 4 is fitted with an open ring sight and can be used in combat for bombardment, creating smoke screens, and for providing night illumination.

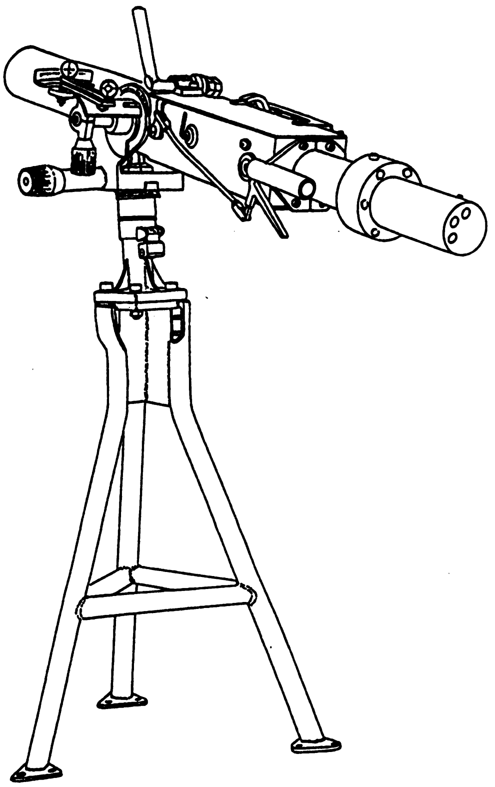
The Mk 4 is a unique weapon in several respects. While it fires standard Army 60-mm mortar ammunition, the weapon itself is designed for, and is used solely by, the Navy. There are two notable features that make it different from



CHARACTERISTICS: (M-60/M-60E3)

- **Weight:** 23 pounds/18.5 pounds
- **Length:** 43.5 inches/42.4 inches
- **Cyclic rate of fire:** 550 RPM
- **Max. effective range:** 1200 yards

Figure 13-4.—A. Standard M-60 MG; B. M60E3.



CHARACTERISTICS

- **Firing modes:** **Trigger and drop**
- **Weight:** **140 pounds**
- **Length:** **55 inches**
- **Sight:** **Open ring**

Figure 13-5.—The Mk 4 naval mortar.

the typical land-based mortar. First, the Mk 4 is designed with recoil and counter-recoil mechanisms. Secondly, it is designed to be free swinging in train and elevation for quick changes in direction, but may also be locked into a fixed firing position.

The Mk 4 is operated by a two-man crew—the mortar captain and the loader. The mortar captain aims the mortar and gives loading instructions to the loader. The loader prepares the ammunition for firing and loads the mortar tube on command from the mortar captain.

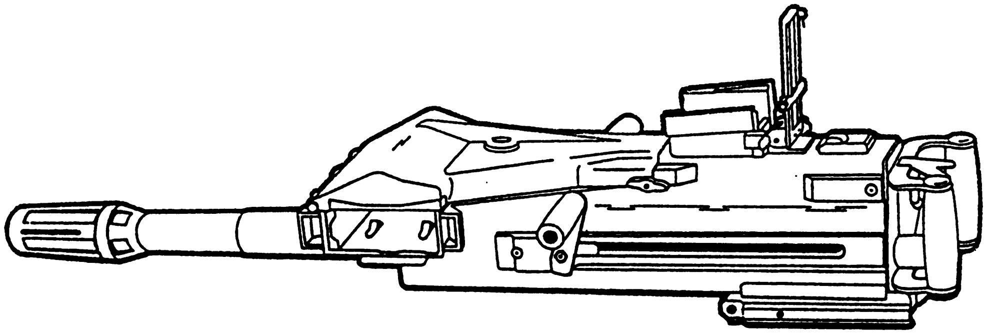
MK 19 MACHINE GUN

The Mk 19 machine gun (fig. 13-6) is belt-fed, air-cooled, and blow-back operated. It fires 40-mm fragmentation and high explosive dual-purpose (HEDP) grenades at a rate of 325 to 375 rounds-per-minute to a maximum range of 2,212 meters. The weapon is intended for antipersonnel and antimaterial use.

There are two versions of the Mk 19 currently in use—the Mod 1 and the Mod 3. The Mod 1 is presently being phased out in favor of the more reliable Mod 3.

SUMMARY

Riverine forces are a unique and highly specialized part of the Navy. They are prepared



CHARACTERISTICS

- **Weight:** **75.6 pounds**
- **Length:** **43.1 inches**
- **Cyclic rate of fire:** **325-375 RPM**
- **Maximum range:** **2212 meters**

Figure 13-6.—The Mk 19 40-mm machine gun.

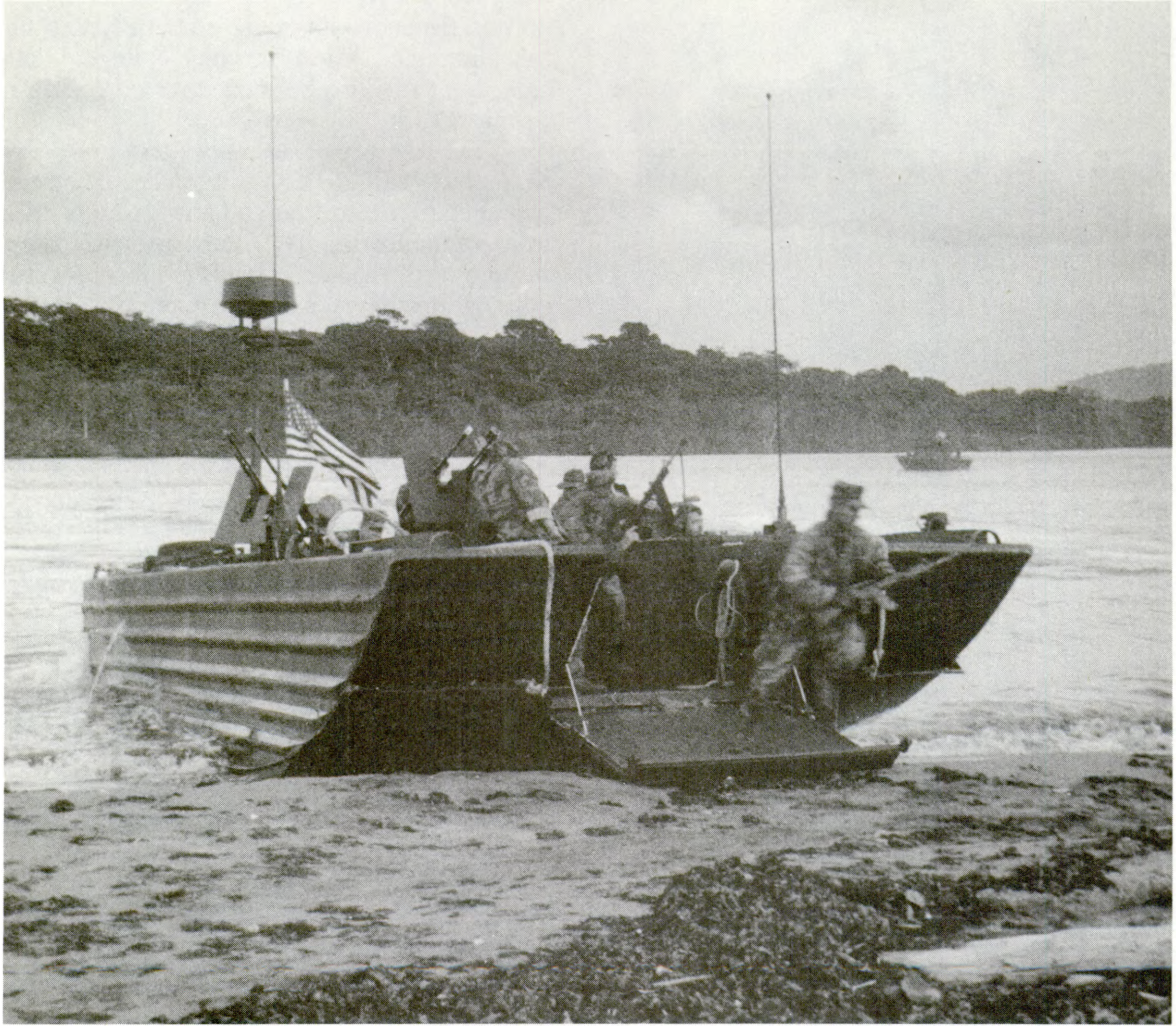


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Figure 13-7.—A Mini-ATC landing troops ashore.

and equipped to carry out both overt and covert operations in conjunction with regular Navy and Marine Corps units, as well as with other government agencies. The boats and weapons described in this chapter can be used in numerous combinations, depending upon the mission and the role of each craft in the mission. Figures 13-7 and 13-8 show Special Boat Unit (SBU) boats in operation. For further information on riverine operations, see NWP-13.

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Browning Machine Gun, Caliber .50 HB, M2, Army Field Manual 23-65, Headquarters Department of the Army, Washington, D.C., 1972.

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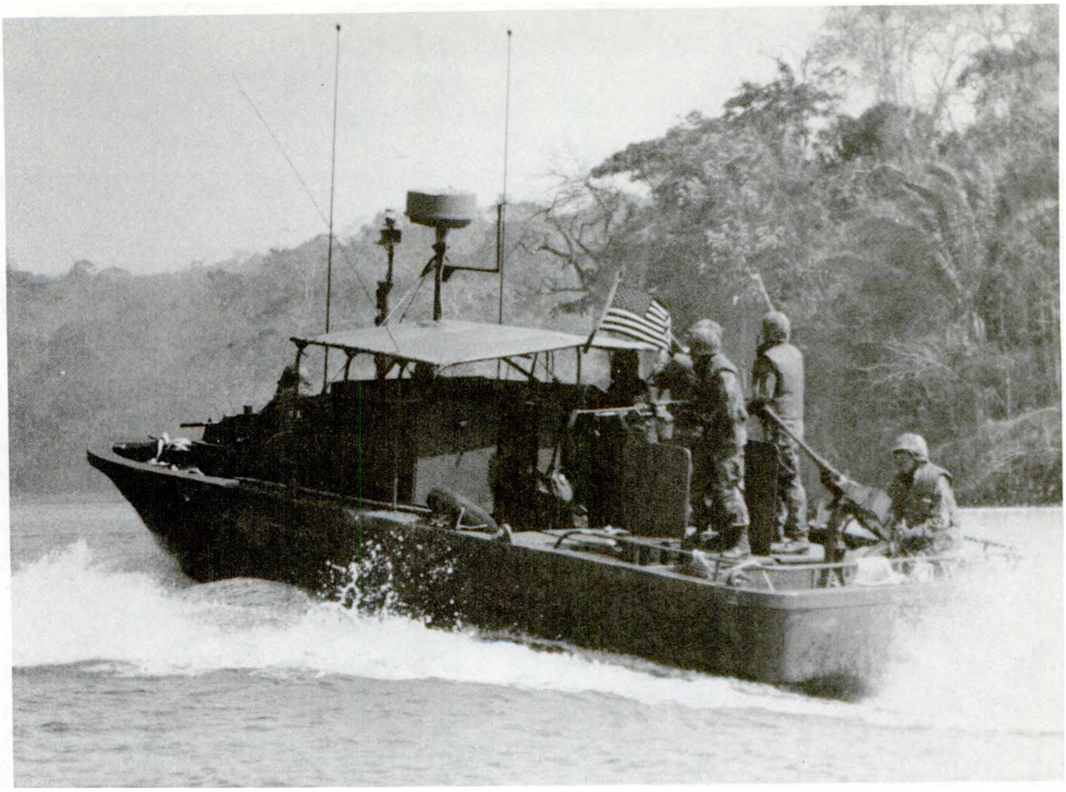

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Figure 13-8.—A PBR on patrol.

CHAPTER 14

UNDERWATER ORDNANCE

Underwater ordnance includes weapons that use an underwater explosion to destroy or disable enemy ships. The effectiveness of underwater ordnance stems from one of the hydraulics principles discussed in chapter 3: the non-compressibility of fluids (water). Since fluids, in this case seawater, are practically incompressible, the force of an underwater explosion is transmitted directly to the hull of the target ship. Some weapons, such as the Tomahawk and Harpoon missiles, may be fired from submarines. However, in terms of modern weaponry, underwater ordnance is limited to torpedoes and mines.

HISTORY OF UNDERWATER ORDNANCE

The first people to use explosives underwater were the Chinese. They discovered that explosives act the same way underwater as they do underground. They placed charges under enemy river boats to destroy them.

The modern ancestor of both torpedoes and mines was David Bushnell's powder keg with contact triggers attached (fig. 14-1). He floated many of them down the Delaware River toward blockading British ships during the American Revolution.

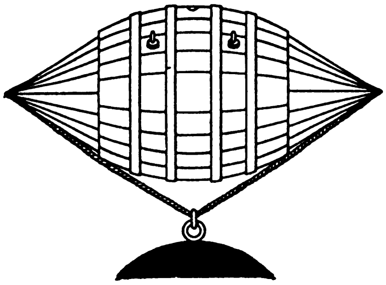


Figure 14-1.—Bushnell's powder keg mine.

During the American Civil War, David Fulton, who was best known for his invention of the steamship, devoted a good part of his life to the successful development of underwater mines. In the Civil War, the Confederates defended Vicksburg by floating mines down the Mississippi River. The first recorded successful use of a mine occurred in 1863 when the federal gunboat, USS *Cairo*, struck mines in the Yazoo River. A year later, a field of 80 mines, which for the first time had safety devices, was laid to defend the city of Mobile, Alabama. It was in the ensuing battle to take the city that Union Admiral Farragut gave his famous command, "Damn the torpedoes—full speed ahead!" In those days mines were often called torpedoes. Throughout the Civil War a total of 35 ships were sunk by Confederate mines. Three of these were Confederate ships sunk by mines that had broken loose from their moorings.

Before proceeding, let us first review the basic description of mines and torpedoes. A mine is a thin-cased weapon filled with high explosives and designed to explode underwater when struck or closely approached by a ship or submarine. A torpedo is a self-propelled weapon that carries a high-explosive charge to an enemy ship. In this chapter, we discuss both mines and torpedoes, as well as some of their delivery systems.

MINES

After the American Civil War, mines and torpedoes became two separate weapon types. Between that time and the beginning of World War I, very little happened in the United States to advance our mine warfare capabilities. Although the United States was not involved in the Russo-Japanese War of 1904, it is worth mentioning because mines played a decisive role in the war. It was in this war that mines saw their first use in a naval action at sea. The Japanese were able to lure the Russian fleet into a minefield, sinking the battleship *Petropavlosk* and killing

Admiral Makaroff. The admiral refused to change course, because he did not consider mines a serious threat. The Russians sank more Japanese ships with mines than by any other form of attack.

Upon entry into World War I, the United States hurriedly developed and produced the Mk 6 moored mine. Procurement of 100,000 of these mines was authorized for placement in the North Sea barrage, which contributed to the mutiny of the German Navy in the last days of the war.

The United States, Britain, and Germany all used mines with devastating effects during World War II. Britain lost 280 combatant and 296 merchant ships to German mines, while the Germans lost 250 combatant and 800 merchant ships to British mines. The Germans planted 266 mines along the eastern seaboard of North America. Nine ships were sunk or damaged as a result of these mines.

Much to the surprise of United Nations commanders, the North Koreans effectively used mines around Wonson Harbor.

During the war with North Vietnam, the United States planted more mines than in all previous conflicts combined. The famous mining of Haipong Harbor saw the use of over 11,000 mines and destructors.

TYPES OF MINES

There are two basic types of underwater mines: the bottom mine and the moored mine. The distinction should be fairly obvious: the bottom mine lays on the sea bottom; the moored mine is tethered to an anchor that allows the mine to float at a preset depth. Both are activated by various outside influences. The influences can be magnetic, seismic, or pressure, or any combination of the three. The moored mine, because it floats above the sea bottom, may be planted in much greater depths of water than the bottom mine. Most underwater mines are designed to be planted from either surface ships or aircraft. The only exceptions to this are the Mk 60, which may also be planted from a submarine, and the Mk 67, which can only be planted from a submarine. We will now describe the mines currently in use. Bear in mind that mines and mine warfare are highly classified, so our descriptions will be necessarily brief.

MK 52 AND MK 55 MINES

These two weapons are basically the same. The only difference is in the size of the case and the amount of explosives they contain. The Mk 52 is classified as a 1,000-lb weapon with a 595-lb explosive charge. The Mk 55 is classified as a 2,000-lb weapon with a 1,270-lb explosive charge. Both the Mk 52 and the Mk 55 are bottom mines.

MK 56 MINE

The Mk 56 is a moored mine with a stainless steel case to reduce magnetic interference. The Mk 56 is classified as a 2,000-lb weapon with a 365-lb explosive charge. Figure 14-2 illustrates the mooring sequence of a Mk 56 moored mine. This sequence is common to all moored mines.

MK 60 MINE

The Mk 60 is a moored mine that incorporates a Mk 46 torpedo in a mine case. The Mk 60 programs the torpedo with basic target information, then fires the homing torpedo.

MK 62, 63, 64, AND 65 MINES

The Mk 62, 63, and 64 mines are basically the same as the DSTs described in chapter 12. The main difference is the use of a target detecting device (TDD) instead of a firing mechanism. The Mk 65 is designed as a mine and is classified as a 2,000-lb weapon. Most of the information on the Mk 65 is classified.

MK 67 MINE

The Mk 67 is a submarine-launched mobile mine. It incorporates the Mk 37 torpedo with a mine section. The mine is launched like a torpedo and is self-propelled to a pre-determined location, where it becomes a bottom mine. This weapon is designed for mining operations that require secrecy, allowing the submarine to fire

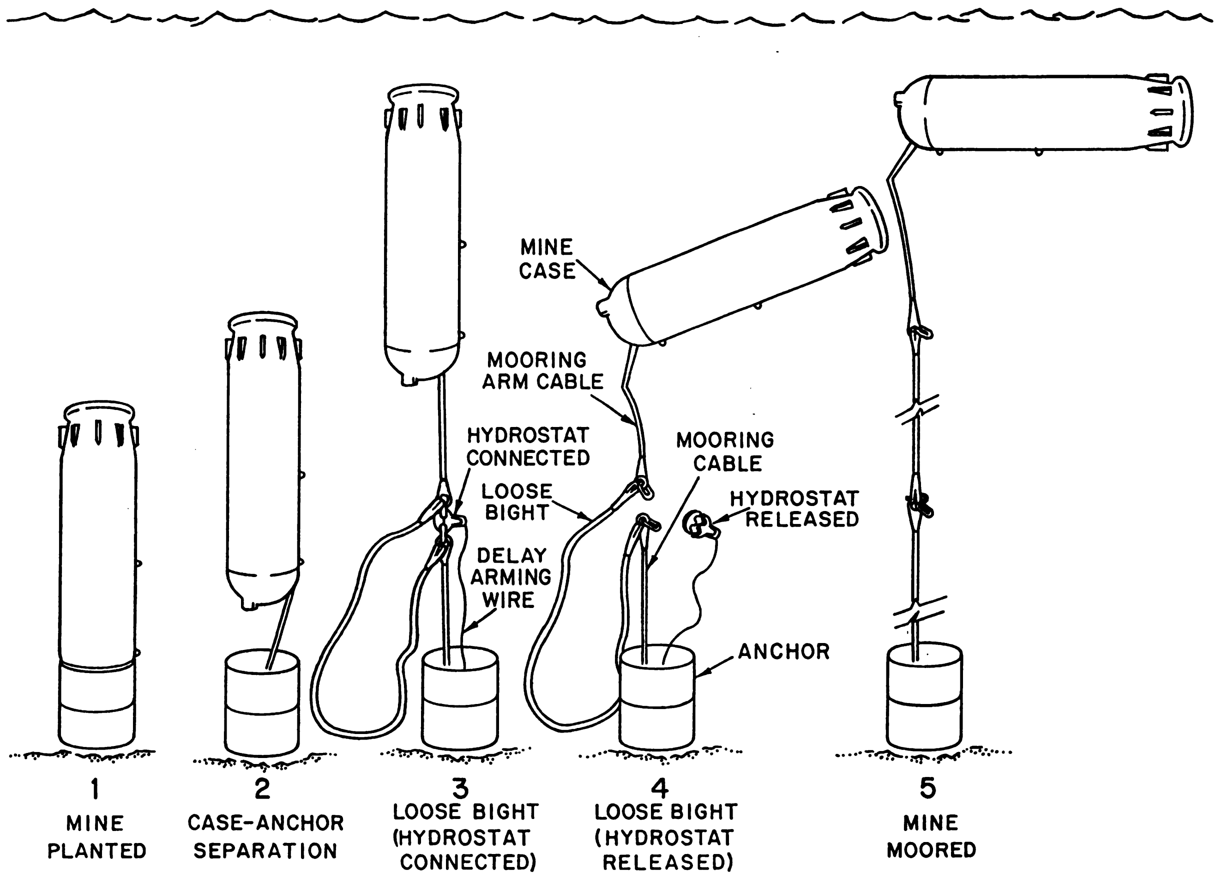


Figure 14-2.—Mooring sequence of the Mk 56 mine.

the weapon from great distances while going undetected.

TORPEDOES

Credit for the first self-propelled torpedo goes to a Captain Lupius of the Australian Navy. Captain Lupius worked out his idea during the American Civil War, but did not have the mechanical ability to actually build the torpedo.

In 1864 he took his plans to Robert Whitehead, a British engineer. After 2 years of work, Whitehead produced a short torpedo, 14 inches in diameter, with 18 pounds of dynamite in its warhead. It was powered by a piston engine, operating on compressed air. Whitehead's first torpedo ran at 6 knots for about 100 yards. On some of its tests, it ran along the surface; on others, it dived to the bottom. Many of the devices invented by Whitehead for this torpedo are still used in modern torpedoes today.

Modern torpedoes are all the homing type. That is, they are equipped with guidance systems that, like a guided missile, detect the target and produce control surface orders to alter the path of the torpedo, allowing it to intercept the target.

TORPEDO COMPONENTS

A torpedo is generally constructed in four or five sections called groups. These groups include the nose, warhead, control, fuel tank, and afterbody groups. The following is a brief description of these groups.

The nose group contains the transducer, transmitter, and receiver, as well as other elements of the homing device. The transducer unit (including the transmitter and receiver) constitutes a miniature sonar system, identical in operation to those described in chapter 2. Its functional purpose, however, is more similar to the guidance system in a guided missile. The sonar unit finds the target and transmits target data to the control section, which generates control surface orders, steering the torpedo to the target. The afterbody contains the propulsion and steering systems. The explosive warhead may be substituted with an exercise warhead for practice shots.

TORPEDO TYPES

There are two torpedoes currently in use by the U.S. Navy with two others being incorporated as replacements. The Mk 48 and the Mk 46 are currently in use, with the Mk 48 Advanced Capability (ADCAP) and the Mk 50, respectively, being phased into service as their replacements. These torpedoes are each described briefly in the following sections. Since much of the information concerning torpedoes is classified, our descriptions will be limited.

Mk 48 Torpedo

The Mk 48 torpedo (fig. 14-3) is a submarine-launched, high-speed, deep-running, long-range, wire-guided torpedo used against submarines and surface vessels. The wire guidance system allows the Mk 48 to be guided wholely or in part by the firing submarine.

The Mk 48 ADCAP torpedo was designed to counter improvements made to enemy submarines, especially the increases in depth and speed.

Mk 46 Torpedo

The Mk 46 torpedo (fig. 14-4) is a two-speed, deep-running, passive or active, acoustic-homing, anti-submarine torpedo. The Mk 46 can be launched from a variety of platforms, including surface ships, submarines, fixed-wing aircraft, and helicopters. Surface ships can launch the Mk 46 torpedo either from the Mk 32 torpedo tubes or as the payload of an anti-submarine rocket (ASROC). The Mk 32 torpedo tubes and the ASROC missile will be briefly described in the next section of this chapter.

Mk 50 Torpedo

The Mk 50 torpedo (fig. 14-5) is a lightweight, acoustic-homing torpedo, developed to replace the Mk 46. The torpedo is designed to counter future enemy submarine improvements in speed, depth, quietness, countermeasures, and damage resistance.

TORPEDO DELIVERY SYSTEMS

Torpedoes, especially the Mk 46 and Mk 50, can be launched from many different platforms using several different delivery systems. The surface ship delivery systems for the Mk 46 and Mk 50 torpedoes will be the main systems

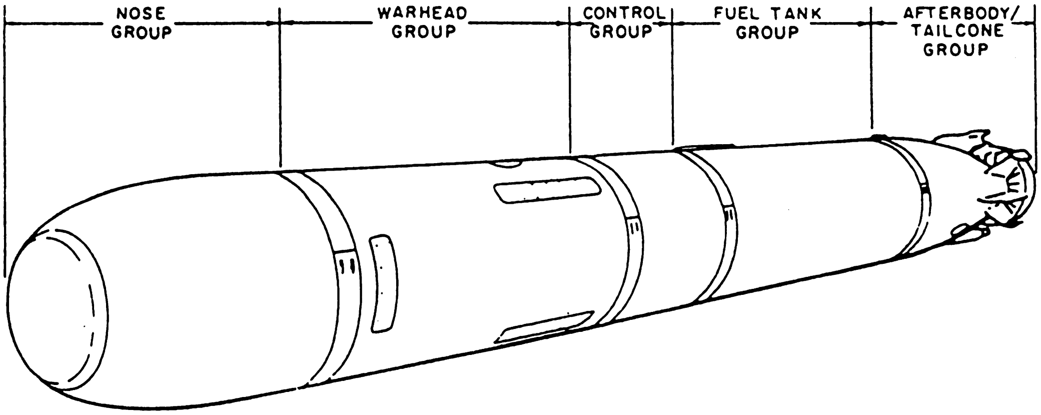


Figure 14-3.—The Mk 48 warshot torpedo.

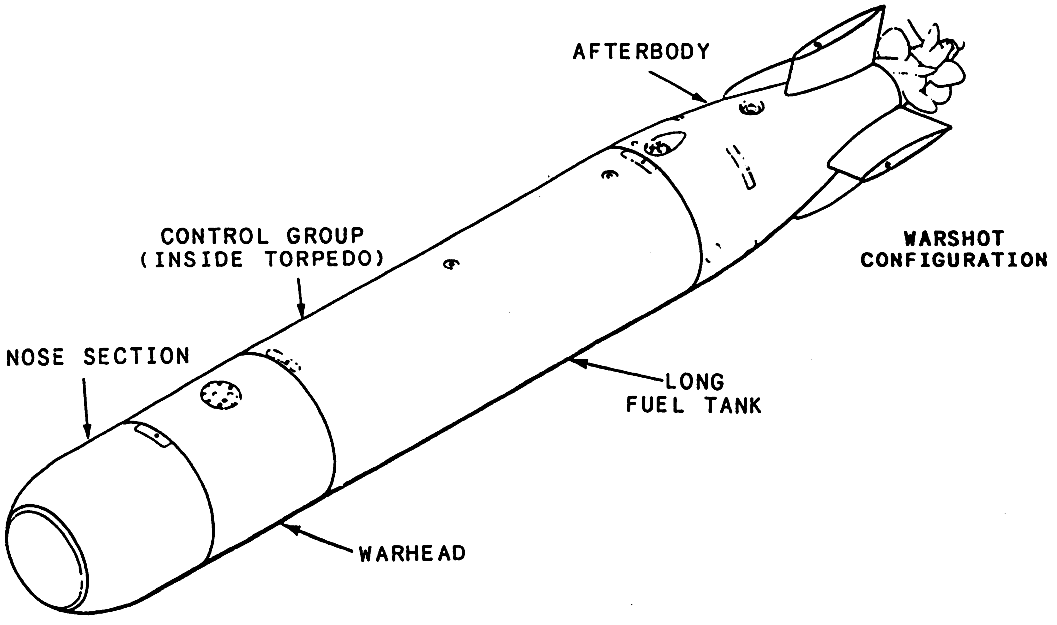


Figure 14-4.—The Mk 46 torpedo.

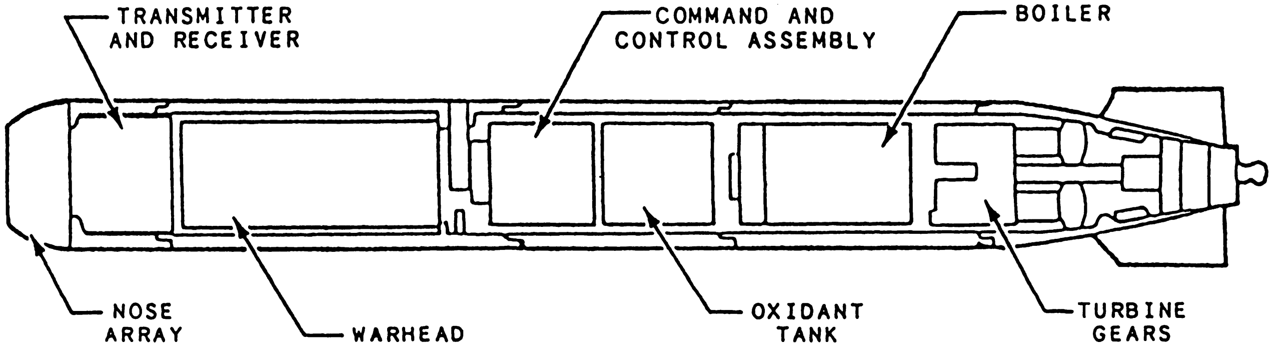


Figure 14-5.—The Mk 50 Torpedo.

described here. The Mk 48 torpedo is currently limited to use as a submarine-launched weapon. This section will concentrate on the Mk 32 torpedo tube and the ASROC missile.

Surface ships may launch the Mk 46 or Mk 50 torpedo either from the Mk 32 torpedo tubes or as the payload of an ASROC missile. Many ships also carry the LAMPS helicopter, which is used not only to locate submarines but also to deliver a torpedo.

Mk 32 Torpedo Tubes

The Mk 32 torpedo tubes come in several different versions. Mk 32 Mods 5, 7, 14, and 15 are deck-mounted, triple-tube trainable mounts; the Mk 32 Mod 9 is a two-tube stationary system, mounted inside a deckhouse. A normal shipboard installation consists of two identical sets of tubes; one set is mounted on the port side, and the other, on the starboard side. The tubes can be fired either remotely (electrically) or locally (manually). However, manual firing is intended for emergency firing only. Other than the obvious difference in the number of tubes, the main difference consists of the internal wiring, which allows each Mod to interface with a different fire control system.

Figure 14-6 illustrates both the triple- and double-tube versions of the Mk 32 torpedo tubes. A cable assembly and arming wire are attached to the torpedo when it is loaded into the tube. Torpedo prelaunch settings are made by the fire control system, through the cable assembly. High-pressure air is stored in the breech mechanism and released into the tube to push the torpedo out and over the side of the ship. The cable assembly and arming wire both pull free of the torpedo at launch. As the arming wire is pulled free of the torpedo, the access to the saltwater battery becomes exposed. Upon entry into the water, the battery fills with seawater and activates the torpedo.

ASROC

The ASROC missile (fig. 14-7) is a solid fuel, rocket-propelled, unguided weapon that is launched from surface ships to destroy submarines. It is launched from the Mk 16 ASROC system, the Mk 41 VLS, and the Mk 10 and Mk 26 GMLS. The missile consists of a torpedo payload connected to the rocket motor by an airframe. The airframe houses the stabilizer, counterweights, and ignition and separation assembly (ISA).

The airframe is composed of two cylindrical half-shells referred to as the upper and lower clamshells. The clamshells are hinged together at

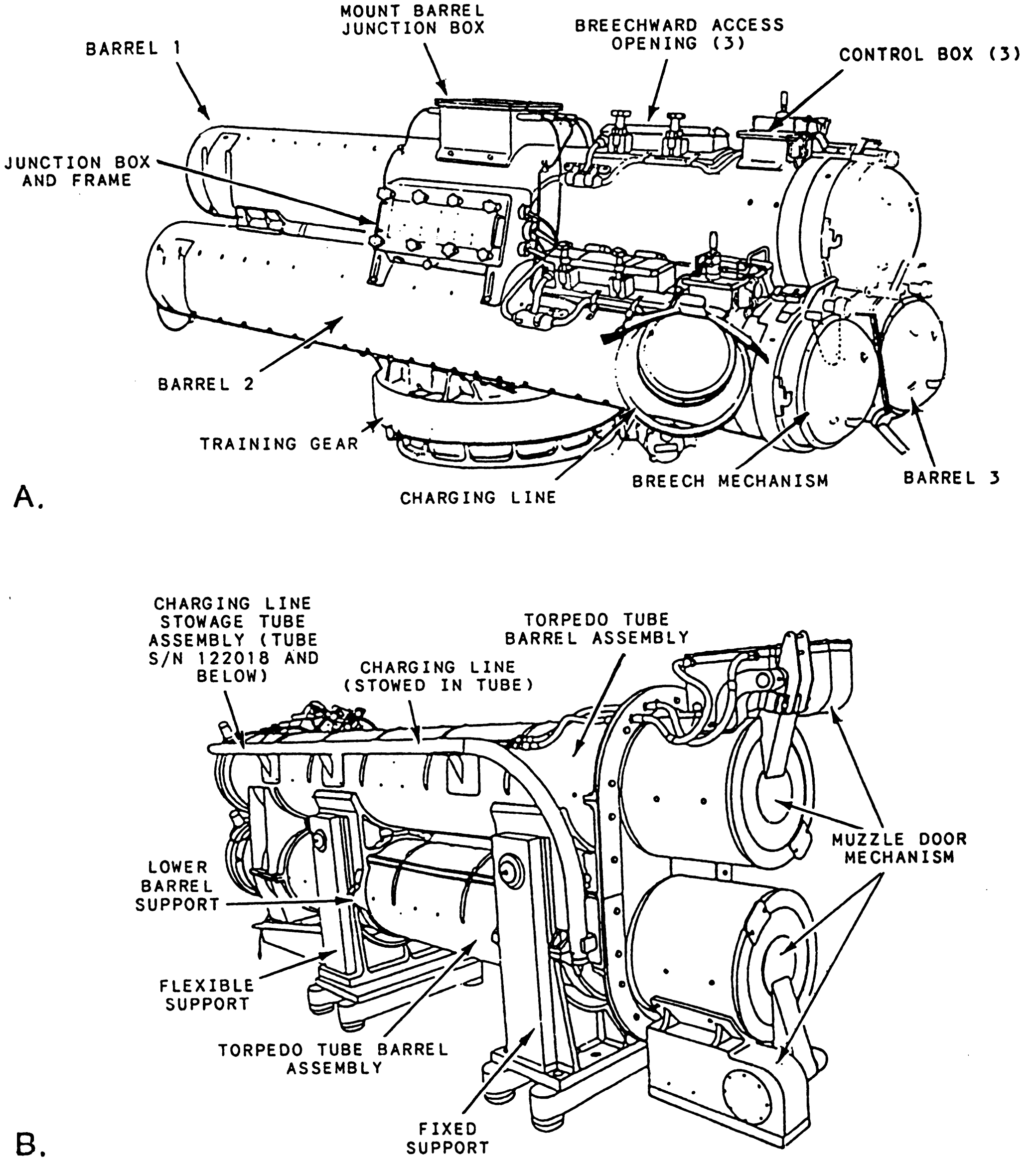

MOUNT BARREL JUNCTION BOX
BARREL 1
BREECHWARD ACCESS OPENING (3)
CONTROL BOX (3)
JUNCTION BOX AND FRAME
BARREL 2
TRAINING GEAR
CHARGING LINE
BREECH MECHANISM
BARREL 3
A.
CHARGING LINE STOWAGE TUBE ASSEMBLY (TUBE S/N 122018 AND BELOW)
CHARGING LINE (STOWED IN TUBE)
TORPEDO TUBE BARREL ASSEMBLY
MUZZLE DOOR MECHANISM
LOWER BARREL SUPPORT
FLEXIBLE SUPPORT
TORPEDO TUBE BARREL ASSEMBLY
FIXED SUPPORT
B.

Figure 14-6.—Mk 32 torpedo tubes: A. Mk 32 Mod 14 triple tube; B. Mk 32 Mod 9 double tube.

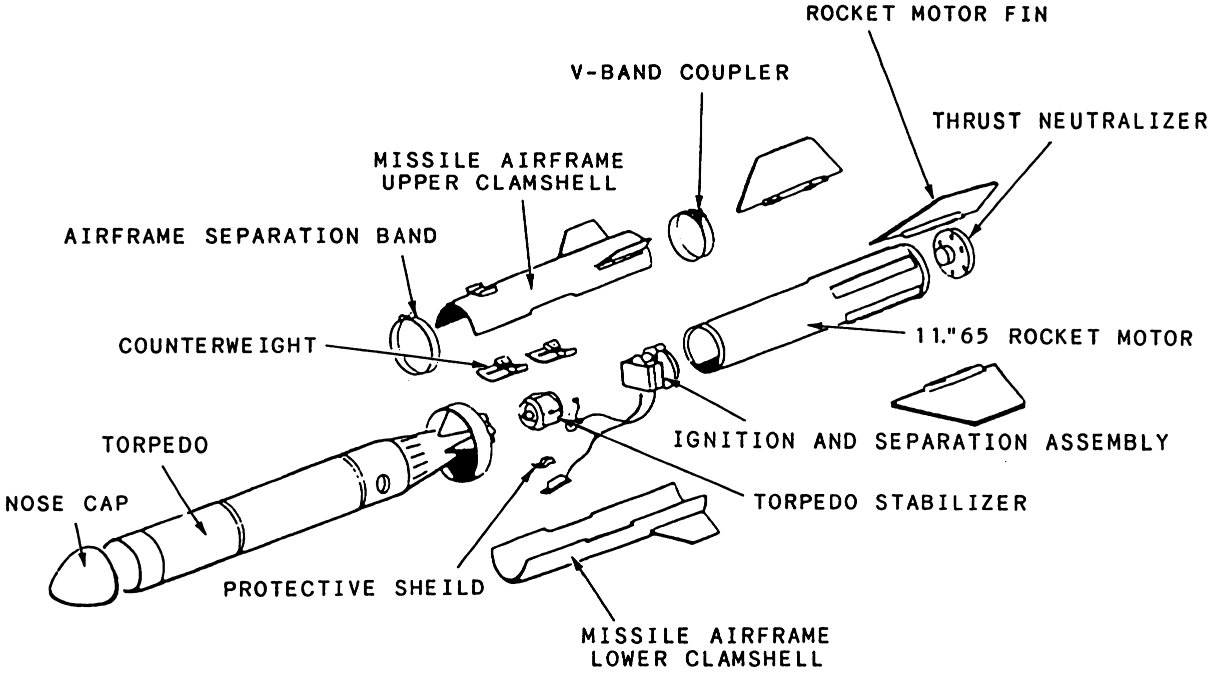


Figure 14-7.—The ASROC missile.

the after end, and clamped to the payload by the airframe separation band at the forward end. The airframe acts to stabilize the missile in flight, deploy the parachute, and pull the arming wire at the desired range.

The ISA determines the range of the missile. It is programmed at launch to initiate rocket motor and airframe separation when the missile has reached a certain velocity, and after a certain time of flight corresponding to the desired range. The rocket motor separates first, then the airframe. After airframe separation, the parachute deploys to decelerate the torpedo to a safe water-entry speed. At water impact, the frangible nose cap shatters while cushioning the shock, and the stabilizer (parachute) is separated by a release mechanism.

The vertical launched ASROC (VLA) missile is a modified version of the standard ASROC missile. This is necessary because the ASROC is fired on a standard trajectory. The VLA, since it is fired straight up and is unguided, requires a mechanism to cause it to roll to the prescribed trajectory. This is accomplished through a thrust vector. The thrust vector is a vane incorporated into the nozzle of the rocket motor, which pivots to deflect rocket motor thrust, causing the missile to roll in the desired direction. Prior to launch, the thrust vector control (TVC) unit is programed by the fire control system as to which direction the vane is to be turned.

The VLA is not currently an operational weapon, but is intended to be placed in service over the next few years. Also, VLA will use only the Mk 50 torpedo as a payload.

SUMMARY

In this chapter we have discussed the history of underwater weapons. We have seen how the primitive mines used by the early Chinese evolved into the highly sophisticated mines and torpedoes of today. We have discussed the two classes of mines, bottom and moored, as well as some of the specific mines in the current U.S. inventory. Finally, we described torpedoes, including ASROC, and some of the delivery systems used in the fleet today. For further information on these types of ordnance, refer to *Torpedoman's Mate Third Class*, NAVEDTRA 10168, and *Mineman 3 & 2*, NAVEDTRA 10166-E.

REFERENCES

Torpedoman's Mate Third Class, NAVEDTRA 10168, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1989.

Mineman 3 & 2, NAVEDTRA 10166-E, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1988.

CHAPTER 15

ORDNANCE MANAGEMENT

In the previous chapters, we discussed the types of ordnance equipment and explosive ordnance currently used by the U.S. Navy. We also related a little history of ordnance development. In this final chapter, we discuss the methods and systems used by fleet units to manage their ordnance inventories.

Ordnance management consists primarily of the ammunition inventory records and the ammunition reporting and ordering requirements listed in SPCCINST 8010.12, *Conventional Ammunition Integrated Management System (CAIMS).* We also discuss some of the ordnance inspections and training requirements you will encounter as an ordnance manager in a fleet unit.

CONVENTIONAL AMMUNITION INTEGRATED MANAGEMENT SYSTEM

The maintenance of an accurate inventory of all explosive ordnance held by a fleet unit is the primary concern of all ordnance managers. The current CNO requirement is that units maintain a 99.5 percent inventory accuracy rate. Foundational to this is the maintenance of the onboard ammunition stock record, commonly referred to as the "ammunition ledger" or just "the ledger." As ammunition is received, expended, or transferred, the ledger is updated to reflect the change. These changes are then reported to Ships Parts Control Center (SPCC), Ammunition Division, for entry into the central computer. Each of these activities is a function of the Conventional Ammunition Integrated Management System (CAIMS).

CAIMS is designed to be a management tool for all echelons of the Navy that are concerned with inventory management. The CAIMS manual (SPCCINST 8010.12) describes the system in detail and the procedures to be used by each type of activity in maintaining and reporting ammunition inventory information. In the following sections, we expand on the major elements of this system, describing their functions and how they interrelate.

AMMUNITION STOCK RECORD

The ammunition stock record, or ledger, is a fleet unit's master record of all ammunition stocks held, as well as a record of past transactions and inventories held. The ledger consists of a Master Stock Record Card (MSRC) for each Navy Ammunition Logistics Code (NALC) or Department of Defense Identification Code (DODIC) held by the unit, and an Ammunition Lot or Serial/Location Card for each different lot or serial number.

Master Stock Record Card

The Master Stock Record Card (MSRC) (fig. 15-1) serves as a record of the total number of rounds of a certain NALC/DODIC held by the unit in each condition code. The MSRC is also used to record information identifying each transaction and the total quantity of ammunition ordered, received, transferred, or expended.

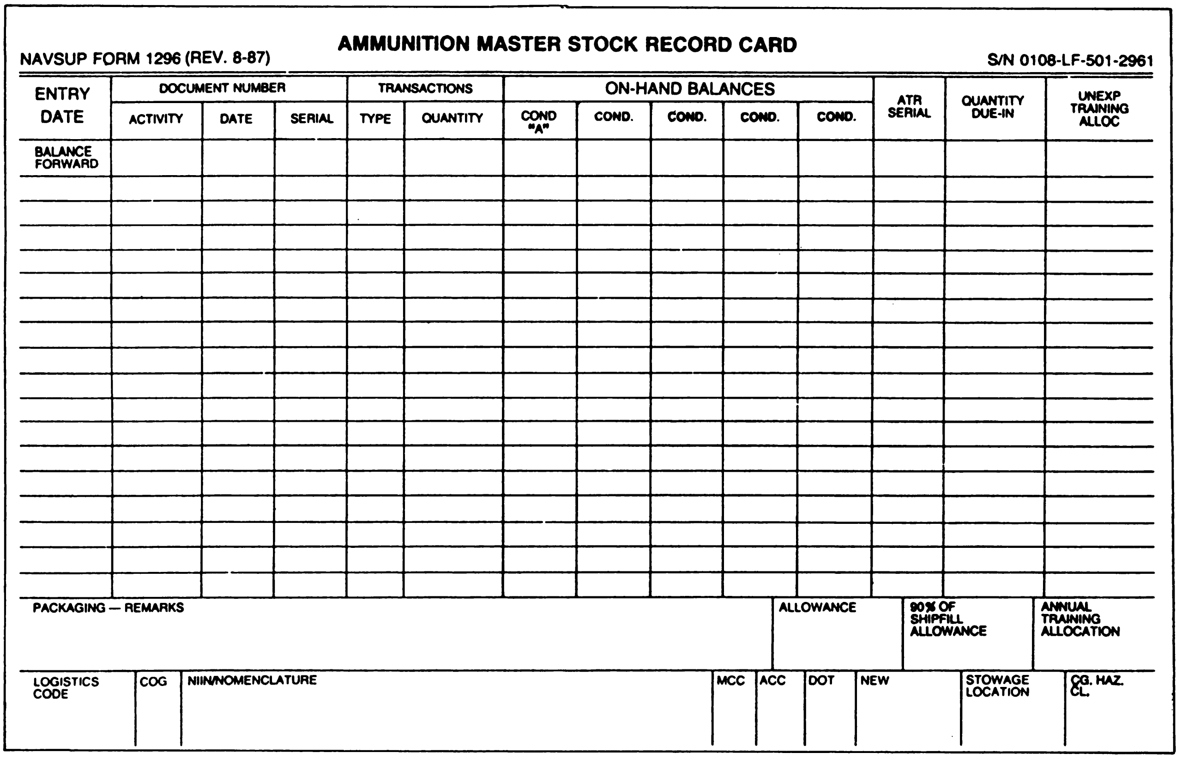
Ammunition Lot/Location Card

The Ammunition Lot/Location Card (fig. 15-2) is used to record the quantity and stowage location of an individual lot of ammunition. Transaction information is also recorded on this card but only for transactions concerning the lot listed.

Ammunition Serial/Location Card

The Ammunition Serial/Location Card (fig. 15-3) is used to account for serialized items such as missiles and torpedoes. Each card accounts for one item. In addition to maintaining an accurate inventory, these cards are used to record the maintenance-due date of the item covered. The maintenance-due date indicates the date the item must be turned in to a weapons facility for inspection and any required maintenance.

Your ammunition ledger will most likely contain all three of these record cards. You will have one Master Stock Record Card for each NALC and DODIC carried. These will be arranged in NALC/DODIC alphanumeric order in a binder or cabinet. Under each MSRC is placed an ammunition lot or serial number location card for



NAVSUP FORM 1296 (REV. 8-87)

AMMUNITION MASTER STOCK RECORD CARD

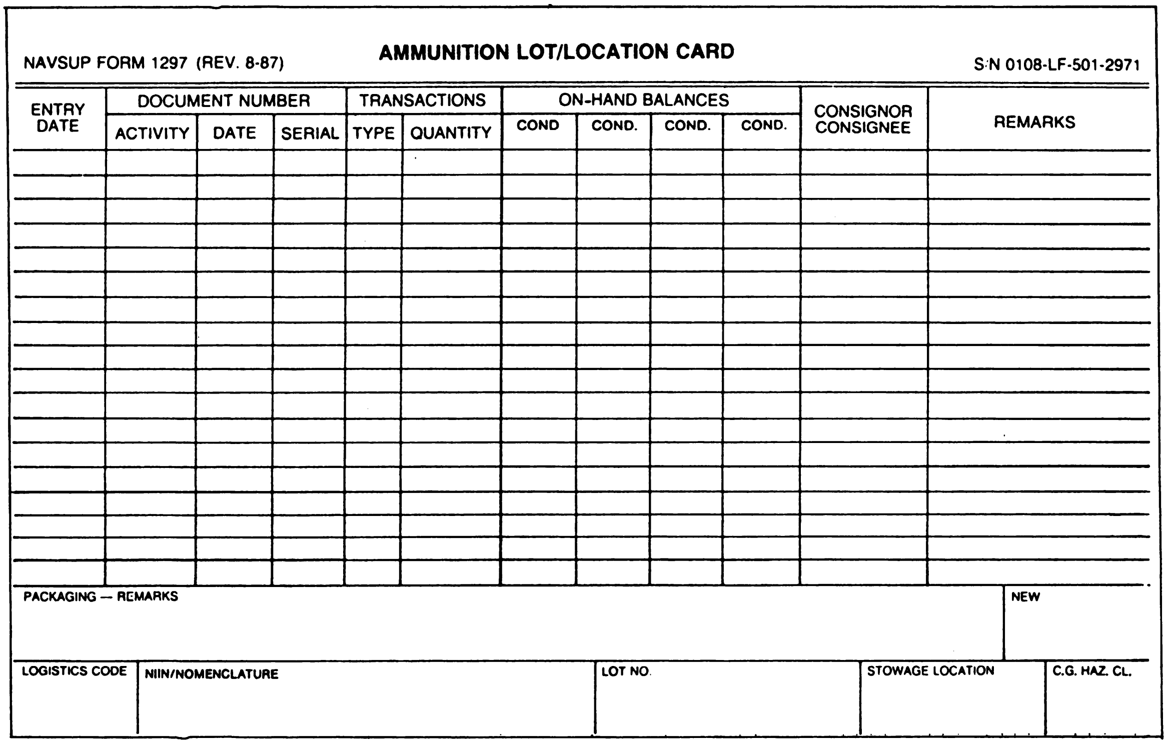
S/N 0108-LF-501-2961

ENTRY DATE	DOCUMENT NUMBER			TRANSACTIONS		ON-HAND BALANCES					ATR SERIAL	QUANTITY DUE-IN	UNEXP TRAINING ALLOC
	ACTIVITY	DATE	SERIAL	TYPE	QUANTITY	COND "A"	COND.	COND.	COND.	COND.			
BALANCE FORWARD													

PACKAGING — REMARKS	ALLOWANCE	90% OF SHIPFILL ALLOWANCE	ANNUAL TRAINING ALLOCATION

LOGISTICS CODE	COG	NIIN/NOMENCLATURE	MCC	ACC	DOT	NEW	STOWAGE LOCATION	CG. HAZ. CL.

Figure 15-1.–Ammunition Master Stock Record Card, NAVSUP Form 1296.



NAVSUP FORM 1297 (REV. 8-87)

AMMUNITION LOT/LOCATION CARD

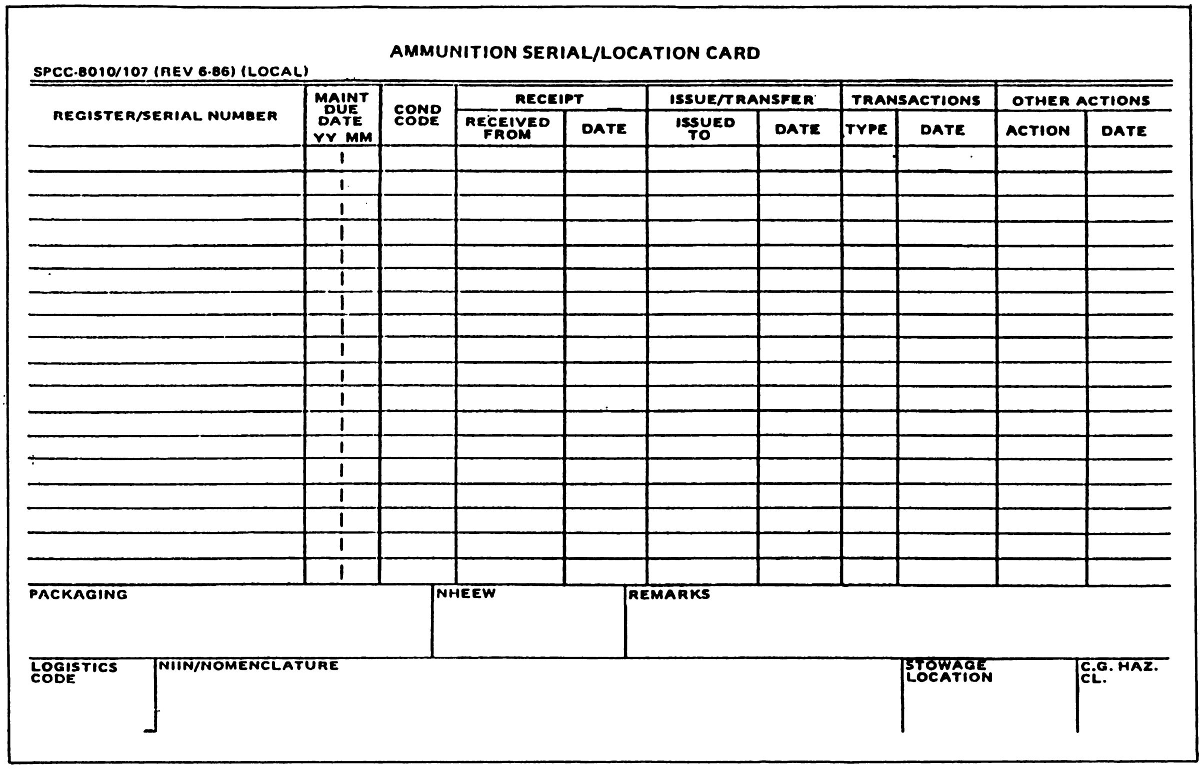
S/N 0108-LF-501-2971

ENTRY DATE	DOCUMENT NUMBER			TRANSACTIONS		ON-HAND BALANCES				CONSIGNOR CONSIGNEE	REMARKS
	ACTIVITY	DATE	SERIAL	TYPE	QUANTITY	COND	COND.	COND.	COND.		

PACKAGING — REMARKS	NEW

LOGISTICS CODE	NIIN/NOMENCLATURE	LOT NO.	STOWAGE LOCATION	C.G. HAZ. CL.

Figure 15-2.–Ammunition Lot/Location Card, NAVSUP Form 1297.



SPCC-8010/107 (REV 6-86) (LOCAL)

AMMUNITION SERIAL/LOCATION CARD

REGISTER/SERIAL NUMBER	MAINT DUE DATE YY MM	COND CODE	RECEIPT		ISSUE/TRANSFER		TRANSACTIONS		OTHER ACTIONS	
			RECEIVED FROM	DATE	ISSUED TO	DATE	TYPE	DATE	ACTION	DATE
	I									
	I									
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PACKAGING	NHEEW	REMARKS

LOGISTICS CODE	NIIN/NOMENCLATURE	STOWAGE LOCATION	C.G. HAZ. CL.

Figure 15-3.–Ammunition Serial/Location Card, NAVSUP Form 1356.

each lot or serial-numbered item carried of that NALC/DODIC. As ammunition is ordered, received, transferred, or expended, it is recorded on the cards. First, the total number of rounds involved is entered on the Master Stock Record Card for that particular NALC/DODIC. The total number is then broken down by lot or serial number, and each different number entered on the appropriate location card. All entries are to be made in ink or typed. These cards are required to be retained for 1 year after the item is expended or transferred.

The cards in the ammunition ledger contain much more information than what has been presented here. Chapter 12 of SPCCINST 8010.12 provides detailed guidance on the makeup and maintenance of the ammunition ledger.

AMMUNITION TRANSACTION REPORTS

Each time a piece of ammunition is expended, transferred, received, or changes condition code, an Ammunition Transaction Report (ATR) must be submitted to update CAIMS. This is normally required to be done within 24 hours of the event. ATRs are sent by Naval message in accordance with the instructions listed in SPCCINST 8010.12, chapter 8. A copy of each ATR message is maintained in a file and kept with the ledger. The ledger and the ATR file must match 100 percent. As an ordnance manager, you should view these two records as your primary concern; they should be kept in perfect order.

AMMUNITION REQUISITIONS

Fleet units requisition all non-nuclear ordnance using the MILSTRIP (Military Standard Requisitioning and Issuing Procedures) format in a Naval Message. MILSTRIP relies upon coded data for processing requisitions by means of automatic data processing equipment. Each ship is provided with an ammunition allowance list of one form or another, depending on its status/mission. The ship-fill allowance list is the one you will be primarily concerned with. It lists the ammunition types and quantities authorized for issue in support of that ship's mission. This list includes the training allowance. All ammunition requisitions must be made with the allowance list in mind. Training allowance increases may be requested.

At this writing, ammunition recording, requisitioning, and reporting are in the process of being automated throughout the fleet. The ordnance manager will maintain his or her ledger and generate requisitions and ATRs all from the same computer terminal. The format, however, will remain the same.

There are many requirements and special instructions involved in the preparation of an ammunition requisition. The mechanics of requisitioning ammunition are well beyond the scope of this manual. Refer to chapter 8 of SPCCINST 8010.12 for detailed information concerning ammunition MILSTRIP requisitions. Your supply officer and the ship's Storekeepers (SKs) are also excellent sources of expertise concerning requisitions.

ORDNANCE INSPECTIONS

Every gun and missile system, and its associated magazines, is subject to regular inspection by the ship's crew and by outside activities. Notice that we have included gun mounts and missile launchers in this section. This is because both gun mounts and missile launchers are, in fact, ordnance-handling devices. Prior to firing, which has its own hazards, the systems themselves transport hundreds, and sometimes thousands, of pounds of ordnance automatically from the magazine area to the point where it can be fired. This has training implications; training is discussed later in this chapter.

The Ships' Maintenance and Material Management (3-M) System covers the majority of scheduled ordnance inspections conducted by the ship's crew. Other unscheduled inspections primarily consist of system adjustment checks, which are accomplished as the situation requires. Criteria for these unscheduled checks is found in the maintenance publications for that system. Inspections performed by outside activities serve to verify the readiness of a unit by how well they conform to storage, handling, maintenance, and administrative requirements. These inspections are normally performed by a representative of a Mobil Technical Unit (MOTU) or by NAVSEA. In this section, we focus primarily on the 3-M System and the types of scheduled inspections it covers. Inspections performed by outside activities are briefly discussed at the end of this section.

THE 3-M SYSTEM

The 3-M system provides fleet units with a system of uniform maintenance standards and inspection criteria, as well as a system of recording and reporting equipment deficiencies. The 3-M system consists of two subsystems: (1) the Planned Maintenance System (PMS), and (2) the Maintenance Data System (MDS). In this section, we provide you with a basic functional description of each of these systems. The detailed requirements of these systems are outlined in OPNAVINST 4790.4, chapters 5 and 9, respectively.

Planned Maintenance System

The Planned Maintenance System (PMS) consists of a system of schedules and preventive maintenance guidelines for the routine upkeep and inspection of each system in use by the Navy. PMS maintenance actions outline the minimum requirements necessary to maintain equipment in a fully operable condition, and within specifications. PMS procedures, and the periodicities at which they are to be accomplished, are developed based on sound engineering practices, practical experience, and technical standards. These procedures are printed on cards designated Maintenance Requirement Cards (MRCs). MRCs provide detailed procedures for performing preventive maintenance. They list the exact steps and state by whom and with what resources a specific requirement is to be accomplished. Maintenance requirements are scheduled using a cycle schedule, from which quarterly and weekly schedules are derived. A weekly report, submitted to the unit's commanding officer, details the checks scheduled for that week and their status. Completed checks are listed, with the maintenance man identified by name. A record of the last 13 weeks of these reports is maintained in the work center. It is referred to as the "13-week" file.

Maintenance Data System

The Maintenance Data System (MDS) consists of a system of reports, originating from the maintenance man, concerning the existence of equipment failures, malfunctions, or other required corrective maintenance actions. Information submitted into the system becomes available to all echelons of management throughout the Navy. Information on maintenance actions not yet completed (deferred) is used to produce a report for the shipboard manager called the Current Ship's Maintenance Project (CSMP). The CSMP is a management tool for scheduling the completion of these maintenance actions either by the ship's force or by an outside support activity. Outside support activities include tenders, Ship's Intermediate Maintenance Activities (SIMAs), and shipyards. The more clearly your problems and their proposed solutions are described in the write-up, the more useful your CSMP will be to you and the support activities sent to help you.

Now that we have described the basics of the 3-M system for you, we will discuss some of the types of inspections held on ordnance equipment and ordnance. One of the most important ordnance equipment inspections covered by PMS is the one performed prior to firing. Prefire checks should be accomplished in exact accordance with the appropriate MRC. These checks normally include the verification of fluid levels in hydraulic systems; pressure levels in air and compressed gas systems; the functioning of the firing circuit; and the accuracy of gun or missile launcher orders. Other checks on ordnance equipment consist primarily of the routine lubrication of mechanical devices.

Ordnance (storage) inspections consist of daily, weekly, monthly, and quarterly magazine inspections. The MRCs for these inspections amount to a listing of storage requirements taken directly from the governing publications and instructions, predominantly OP-4. Magazine inspections check for proper storage of ammunition, good housekeeping, the security of fasteners for installed equipment, the operation of installed equipment, and the existence of correct stenciling. If these checks are properly accomplished, you should rarely get "hit" on an Explosive Safety Inspection (covered in the next section). We make note of this at this point because these checks require an extensive knowledge on the part of the maintenance man about seemingly insignificant details. It is easy for a maintenance man who is not thoroughly trained to overlook a section or just neglect to complete every critical step of the check because it may have seemed unimportant. Train your people on the MRCs they are required to accomplish and avoid this problem.

The Planned Maintenance System also covers the testing and inspection of the magazine sprinkler systems installed in your magazines and missile checkout and assembly areas. These MRCs detail the test and inspection procedures listed in the *Description, Operation, and Maintenance Handbook for Magazine Sprinkler Systems*, S9522-AA-HBK-010. These are the same procedures that inspectors from outside activities will use when they come aboard to inspect your system.

By now it should be plain to see that the proper accomplishment of all assigned PMS is the key not only to satisfying the requirements of outside inspection teams but also to keeping your systems operational.

INSPECTIONS

As an ordnance manager, you can expect your records, equipment, and magazines to be subjected to periodic inspection from an outside activity. As we stated earlier, these inspections serve to determine the readiness of a unit, based on how closely they conform to standards. The following is a listing of ordnance and ordnance equipment inspections that you can expect to encounter. The teams that perform these inspections are also usually available on request for an assist visit. Assist visits basically amount to a training inspection prior to the inspection held for the record.

Non-Nuclear Ammunition Inventory Accuracy (NAIA) Review

The NAIA review is a NAVSEA inspection conducted by NWSC Crane (Code 506) to verify the accuracy of a unit's ammunition inventory. The team arrives on board with a copy of the current CAIMS data base information for that unit. This data consists of the stock status information for each NALC/DODIC carried by the unit. The inspection consists of the team's holding a physical inventory of some or all of the ammunition assets of the activity. The resulting inventory is verified against the ammunition ledger, which is also checked for completeness and accuracy. The totals from the ledger are then compared with the totals carried on the CAIMS data base. The ATR file is also inspected for completeness.

3-M Inspection

Periodically, as ordered by your type commander, your ship's 3-M records and maintenance accomplishment will be inspected. The inspection is accomplished by a team assigned by the type commander. The team will first check your maintenance schedules and the 13-week file to ensure that they match. Every check listed on the cycle schedule for accomplishment during the current quarter must be listed on the current quarterly maintenance schedule. The 13-week file must also accurately reflect the status of all maintenance checks scheduled for that time period. Once all of these records are inspected, a check indicated as having been accomplished during the last 13 weeks will be selected for a spot check. The maintenance man recorded as having accomplished the check will then escort the inspector to the equipment covered by the check, produce the tools required by the MRC, and walk through the check with the inspector. Inspectors will also check your MDS records to ensure that they are complete and accurate.

INSURV

The Board of Inspection and Survey (INSURV) was established by Congress as a trial board to advise the

Secretary of the Navy regarding acceptance of newly constructed ships and the suitability of active fleet units for further service. Additionally, the INSURV Board has been tasked with keeping the Chief of Naval Operations (CNO) informed of the material condition of forces afloat through scheduled inspections. These inspections are conducted as Underway Material Inspections (UMIs), which consist of operational tests or demonstrations of major systems and equipments, and a material inspection of the entire ship. All discrepancies are put on your CSMP by the INSURV Board. Ideally, all discrepancies should already be listed on your CSMP. Many a workcenter supervisor has spent the weeks before an INSURV inspection frantically recording discrepancies to avoid being embarrassed. In effect, what you are saying to the INSURV Board by not having problems identified on your CSMP is that you did not know they existed.

Explosive Safety Inspection

OPNAVINST 8023.2, enclosure 1, assigns Naval Sea Systems Command (NAVSEA) with the responsibility of establishing Navy explosive ordnance safety standards. This instruction also tasks NAVSEA with the responsibility for arranging regular inspections of sea and shore units that handle and store ammunition. This instruction and OPNAV 8023.23, which defines inspection procedures, are the policy documents that define the Navy's explosive safety program. They should be read and understood in their entirety by all ordnance managers.

The Explosive Safety Inspection (ESI) is conducted using a set of checklists contained in NAVSAFECENINST 8020.1. The Naval Safety Center produces the checklists pertaining to ordnance safety based on the recommendations made by NAVSEA. NAVSEA Support Centers conduct Explosive Safety Inspections as scheduled by the Type Commanders. The ESI covers all systems relating to explosive safety except magazine sprinkler systems. NAVSAFECENINST 8020.1 contains checklists covering more than just explosive safety, making it a valuable resource for ensuring that all safety standards are met.

These four inspections are not the only inspections you can expect. It is safe to say that every system and subsystem on every ship in the Navy will be inspected at least every 18 months. The bottom line is, if your PMS is properly done, you should pass any inspection sent your way. Proper PMS accomplishment is directly correlated to the level of training you provide your people. In the next section, we discuss some of the training requirements associated with the ordnance world.

TRAINING REQUIREMENTS

With the complexity of modern systems and the destructiveness of modern explosive ordnance, continuous training is critical to safe operations. The Navy has two primary onboard training programs that pertain to ordnance handlers. They are the Personnel Qualification Standards (PQS) and the Explosive Handling Personnel Qualification and Certification (Qual/Cert) Program. Both are described briefly in the following sections.

PERSONNEL QUALIFICATION STANDARDS

The Personnel Qualification Standards (PQS) program is a central component of shipboard on-the-job training (OJT). It provides the minimum requirements to qualify on a watchstation/workstation, such as mount captain or magazine sprinkler operator. The PQS program consists of a Standards booklet and progress chart. There are Standards booklets for each watchstation/workstation. The progress chart is posted in the workcenter, where it is updated periodically to reflect each person's accomplishments.

The Standards booklet contains questions you must be able to answer and performance items you must be able to do in order to qualify for a particular watchstation/workstation. The booklet is broken down into three basic sections: Fundamentals, Systems, and Watchstations/Workstations. The Fundamentals section identifies the basic knowledge necessary to do the job properly. In Systems, the subject is broken down into functional sections. The Watchsection/Workstation portion contains the procedures you need to know to properly perform your job.

One or more Qualification Petty Officers are assigned for each watchstation/workstation. The Qualification Petty Officer is the subject matter expert for that watchstation/workstation. His job is to hold training on the subject and check the achievement of the trainee. As the trainee masters each topic, the Qualification Petty Officer signs it off in the Standards booklet.

The PQS training system can be a highly successful and valuable tool if properly administered, and Qualification Petty Officers do not "give away" signatures.

EXPLOSIVES HANDLING PERSONNEL QUALIFICATION AND CERTIFICATION (QUAL/CERT) PROGRAM

The requirements of the Explosives Handling Personnel Qualification and Certification (Qual/Cert) Program are defined in COMNAVSURFLANTINST 8023.4/COMNAVSURFPACINST 8023.5. The program consists of a series of certification levels, definitions of work tasks, and categories or families of explosive devices. Anyone who handles ammunition or operates ammunition-handling equipment must be certified under this program. Remember, this also pertains to gun mount and missile launcher operators.

An individual is trained and certified to perform specific work tasks on individual families of ordnance. Refer to tables 15-1, 15-2, and 15-3 for definitions of certification levels, work tasks, and a sample of families of explosive devices.

Table 15-1-Certification level qualification standards

CERTIFICATION LEVEL	QUALIFICATION STANDARD
IN TRAINING (IT)	1. Incumbent is required, by nature of duty, to perform work tasks with explosive devices while under direct supervision of a certified Team Leader (TL) or Individual (I). 2. Incumbent is receiving training on newly introduced explosive devices for which inert training devices are not avilable. 3. Incumbent shall not work with explosives unless supervised by (TL) or (I). 4. This level of certification is temporary until such time full qualification justifies certification at a higher level, e.g., TM, I, etc .
TEAM MEMBER (TM)	BASIC QUALIFICATION. Personnel are aware of basic safety precautions relative to the work task and explosive devices concerned, have received formal and/or on-the-job training, and have been recommended by their immediate supervisor. May not work with ordnance unless supervised by (TL) or (I). NOTE: TM certified personnel will perform in team concept only under supervision of a certified team leader.
INDIVIDUAL (I)	1. Same as for team member (TM) above. 2. Has sufficient knowledge and has demonstrated the proficiency of the work task alone, or trains others in safe and reliable operations. 3. Capable of interpreting the requirements, applicable checklists, SOP, and assembly/operating manuals.
TEAM LEADER (TL)	1. Same as for team member (TM) and individual (I) above. 2. Has sufficient knowledge and has demonstrated the proficiency to direct the performance or training of others, in safe and reliable operations.
QUALITY ASSURANCE (QA)	1. Same as individual (I) or team leader (TL) above. 2. Must have detailed knowledge and ability to train others in applicable explosive device/systems inspection criteria and be able to decide that the necessary assembly or installation procedures have been completed per applicable directives. NOTE: Only TM, I, TL, and QA are interrelated. Certification at the QA level automatically assumes the individual has all knowledge and skill levels required of the TM, I, and TL member
SAFETY OBSERVER (SO)	1. Must have sufficient knowledge of safety procedures and the functioning of safety devices to decide subsequent reaction when safety procedures or devices are not properly used. 2. Certification at the SO level does not require prior certification at any other level. NOTE: This certification level is not restricted to the most senior within a unit. A junior who possesses the foregoing standards and demonstrated maturity may likewise be certified.

Table 15-2.–Work task code definitions

1. Stowage – The physical act of stowing explosive devices in designated and approved magazines and ready service lockers.
2. Handling – The physical act of moving explosive devices manually or with powered equipment within the confines of the ship or within an area authorized for handling ashore.
3. Assembly/Disassembly – Physically mating/unmating explosive device components to form a complete round including torpedo banding. This work task code is used only when assembly/disassembly of the explosive device is authorized at the fleet level.
4. Load/Download – The physical act of installing/removing explosive devices including cartridge-actuated devices into/from the vehicle from which initiation is/was intended, e.g., launchers, projectors, racks, gun barrels, etc.
5. Arm/De-arm – The physical act of rendering explosive devices from a safe condition to ready-for-initiation or returning explosive devices from the ready-for-initiation state to a safe condition.
6. Explosive Driver – An individual who operates self-propelled material handling equipment to transport explosive devices either ashore or afloat. Must meet all requirements of NAVSEA OP 4098 (and COMNAVSURFLANTINST 9093.3 for NAVSURFLANT activities) as a qualification standard before certification.
7. Magazine Inspection – Capability of detecting improperly secured stowage, unsatisfactory packaging, unusual fumes or odors and any other abnormal conditions as defined in NAVSEA OP 4/NAVSEA OP 5 and appropriate Maintenance Requirement Cards (MRC) in explosive devices stowage spaces, magazines, and lockers.
8. Missile System Cycling/Maintenance – Physical act of conducting cyclic operational tests, troubleshooting, repair, and performance of periodic maintenance of GMLS.
9. Gun System Cycling/Maintenance – Physical act of conducting cyclic operational tests, troubleshooting, repair, and performance of periodic maintenance of gun systems.
10. Torpedo System Cycling/Maintenance – Physical act of conducting cyclic operational tests, troubleshooting, repair, and performance of periodic maintenance of torpedo systems.
11. Equipment Operator – An individual who operates non-mobile powered handling equipment (hoists, winches, cranes, elevators, conveyors/transporters, etc.) for handling explosive devices.
12. Testing – The physical act of conducting tests on explosive/firing devices, e.g., AIM-9 umbilical tests, continuity tests on SUU-25/44 flare dispensers and LAU 61/68/10 rocket launchers.
13. Sprinkler System – The physical act of maintaining troubleshooting, testing, flushing, and operating shipboard sprinkler systems (wet or dry as applicable).

Table 15-3.–Families of explosive devices (partial list)

1. Gun ammunition
   a. Propelling charges
      (1) Bag charges
      (2) Cartridge cases
   b. Projectiles (separate loading)
   c. Fixed ammunition (through 76mm)
   d. Fixed ammunition (3" and above)
   e. Saluting charges
   f. Small arms ammunition
2. Rockets
   a. CHAFROC
   b. RBOC/SRBOC
   c. Warhead, 2.75"
   d. Warhead, 5.0"
   e. Fuzes, nose
   f. 2.75" motors (Mk 4/Mk 40/Mk 66)
   g. 5.0" motors (Mk 71/Mk 72)
   h. 5.0" rocket launcher (LAU-10)
   i. 2.75" rocket launcher (LAU 61B/A and LAU 68C/A)
   j. 2.75" rocket launcher (LAU 61C/A and LAU 68D/A
   k. Smokey Sam Simulator rocket and ignitor

The key to the Qual/Cert program is documented training. In the past, ammunition handlers were arbitrarily certified without recorded training to substantiate the certification awarded. This is no longer the case. Your certification program is worthless without documented training in the individual training records of the certified personnel. It is highly recommended that ammunition handler training be recorded in the individual's training record using a format that parallels the certification format. Figure 15-4 shows a sample certification sheet for an individual certified to handle and stow small arms ammunition, gun projectiles, and cartridge-case-type propelling charges at the Team Member level.

The Qual/Cert board is appointed in writing by each unit's commanding officer. Each board member except the chairman must be certified at or above the level to which he is allowed to sign on the certification sheet.

SUMMARY

Ordnance management involves a variety of duties. You must first keep track of the ordnance in your possession. This is accomplished using the different elements of the CAIMS system. CAIMS provides a complete system of recordkeeping, requisitioning, and reporting procedures. Your preventive maintenance must be accomplished strictly by the MRCs, with all discrepancies noted in the CSMP. You must also train your people on the safe handling of explosive ordnance. Training is an ongoing process, using PQS and the Qual/Cert program as guides to continuously educate ordnance handlers. Finally, as with all critical functions, you will be inspected regularly. These inspections serve to verify your compliance with prescribed procedures. Therefore, you should never have to "get ready" for an inspection.

As an ordnance manager, you will most likely be a junior officer. Remember that as an officer, you have one of the greatest sources of expertise in the Navy available to you: your Chief. This course is intended to give you the foundational information necessary to ask intelligent questions concerning the ordnance systems you may be tasked to manage. Ask lots of questions.

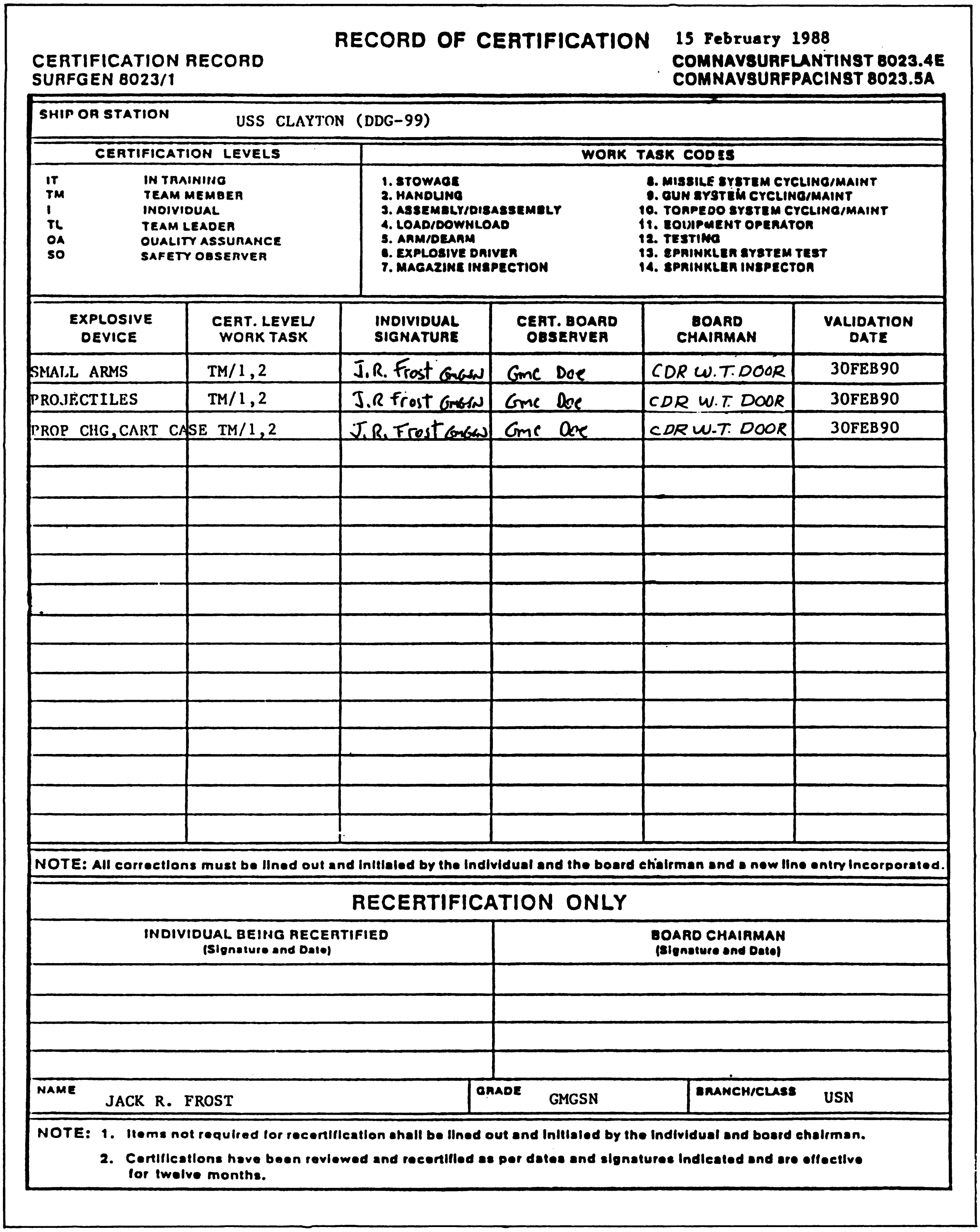
REFERENCES

Explosives Handling Personnel Qualification and Certification (Qual/Cert) Program, COMNAV SURFLANTINST 8023.4E/COMNAV-SURFPACINST 8023.5A, Commander, Naval Surface Force United States Atlantic Fleet and Commander, Naval Surface Force United States Pacific Fleet. 1988.

Non-Nuclear Ammunition Inventory Accuracy (NAIA) Program Procedures Guide For Use In Conducting NAIA Review/Assist Visits To Ordnance Storage Activities, Naval Weapons Support Center, Ammunition Logistics Division (Code 506S), Crane, Ind.

Ships' Maintenance and Material Management Manual, OPNAVINST 4790.4B, Chief of Naval Operations. 1987.

Supply Management of Ammunition, SPCCINST 8010.12D, Navy Ships Parts Control Center, Mechanicsburg, Pa. 1984.



RECORD OF CERTIFICATION 15 February 1988

CERTIFICATION RECORD
SURFGEN 8023/1

COMNAVSURFLANTINST 8023.4E
COMNAVSURFPACINST 8023.5A

SHIP OR STATION USS CLAYTON (DDG-99)

CERTIFICATION LEVELS		WORK TASK CODES	
IT	IN TRAINING	1. STOWAGE	8. MISSILE SYSTEM CYCLING/MAINT
TM	TEAM MEMBER	2. HANDLING	9. GUN SYSTEM CYCLING/MAINT
I	INDIVIDUAL	3. ASSEMBLY/DISASSEMBLY	10. TORPEDO SYSTEM CYCLING/MAINT
TL	TEAM LEADER	4. LOAD/DOWNLOAD	11. EQUIPMENT OPERATOR
QA	QUALITY ASSURANCE	5. ARM/DEARM	12. TESTING
SO	SAFETY OBSERVER	6. EXPLOSIVE DRIVER	13. SPRINKLER SYSTEM TEST
		7. MAGAZINE INSPECTION	14. SPRINKLER INSPECTOR

EXPLOSIVE DEVICE	CERT. LEVEL/ WORK TASK	INDIVIDUAL SIGNATURE	CERT. BOARD OBSERVER	BOARD CHAIRMAN	VALIDATION DATE
SMALL ARMS	TM/1,2	J.R. Frost GMGSN	Gmc Doe	CDR W.T. DOOR	30FEB90
PROJECTILES	TM/1,2	J.R Frost GMGSN	Gmc Doe	CDR W.T. DOOR	30FEB90
PROP CHG,CART CASE	TM/1,2	J.R. Frost GMGSN	Gmc Doe	CDR W.T. DOOR	30FEB90

NOTE: All corrections must be lined out and initialed by the individual and the board chairman and a new line entry incorporated.

RECERTIFICATION ONLY

INDIVIDUAL BEING RECERTIFIED (Signature and Date)	BOARD CHAIRMAN (Signature and Date)

NAME	GRADE	BRANCH/CLASS
JACK R. FROST	GMGSN	USN

NOTE: 1. Items not required for recertification shall be lined out and initialed by the individual and board chairman.

2. Certifications have been reviewed and recertified as per dates and signatures indicated and are effective for twelve months.

Figure 15-4.–Sample Certification sheet.

APPENDIX I

GLOSSARY

ABT–Automatic buss transfer. A device designed to supply continuous electrical power to a piece of equipment from more than one source by automatically switching between primary and secondary sources as they become lost or available.

ACTIVE HOMING–A type of missile guidance that uses a radar transmitter and receiver located in the missile to guide the missile to the target.

AMMUNITION–A contrivance charged with explosives, propellants, pyrotechnics, initiating composition, or nuclear, biological, or chemical material for use in connection with offense or defense, including demolitions.

APPARENT MEAN DISPERSION OF A SALVO IN RANGE (DEFLECTION)–The arithmetical average of the dispersion in range (deflection) of the several shots of a salvo, excluding wild shots.

APPARENT WIND–The wind that is apparent at the observing station; the result of the true wind and the motion of the observing station.

AREA FIRE–Gunfire delivered in a prescribed area.

ARMING–As applied to explosives, the changing from a safe condition to a state of readiness for initiation.

BALLISTIC TRAJECTORY–The trajectory traced after the propulsive force is terminated and the body is acted upon only by gravity and aerodynamic drag.

BALLISTIC WIND–The effective wind, determined by computation, of such force and direction that its action on the projectile during the time of flight will be the same as the combined actions produced by the various true winds acting in the strata through which the projectile will pass as it moves along the trajectory.

BALLISTICS–The science that deals with the motion, behavior, appearance or modification of projectiles or other vehicles acted upon by propellants, wind, gravity, temperature, or any other modifying substance(s), condition(s), or force(s).

BENCH MARK–An optical alignment reference mark.

BOOSTER–A guided missile component used during the initial phase of missile flight to boost the missile to flight speed and altitude.

BORESAFE–A fuze designed to arm only after the projectile passes the gun muzzle.

BOURRELET–The machined surface around the forward portion of a gun projectile body that stabilizes, supports, and guides the nose of the projectile as it passes through the gun bore. The base of the projectile is supported by the rotating band.

BURSTER–Bursting charge or explosive load in a projectile, mine, torpedo, etc. The final unit in an explosive train.

CALL FIRE–Gunfire delivered at the request of troops ashore.

CENTRIFUGAL FORCE–In a rotating object, radial thrust away from center of rotation caused by inertia.

CHAMBER (GUN)–That part of the gun in which the propelling charge is located when the gun is ready to fire.

CLOSE SUPPORTING FIRE–Gunfire delivered on enemy targets that present an immediate danger to friendly forces.

COUNTER FIRE–Gunfire delivered against active enemy guns for the purpose of silencing them.

COUNTERRECOIL SYSTEM–A gun subsystem that pushes the housing back into the battery position after the force of recoil is spent.

DANGER SPACE–The distance, measured in range, that a target may be moved toward the firing point and still be struck by a gun projectile that would have struck the target's lowest point while located at the original position.

DEEP SUPPORTING FIRE–Gunfire delivered on targets not in the immediate area of friendly forces to destroy enemy reserves and weapons.

DEFENSIVE FIRE–Gunfire delivered to protect against counterattack.

DEFILADE FIRE–Gunfire delivered on shore targets located behind some terrain feature.

DETONATION–Violent chemical action initiated by a shock and producing a shock wave, heat, and gases. High explosives detonate, while low explosives (propellants) burn at a high rate.

DIRECT FIRE–Gunfire, delivered on a target, that uses the target itself as an aiming point.

DISPERSION–The distance of the point of impact of a particular shot from the MPI of the entire salvo. Dispersion in range is measured parallel to the line of fire; dispersion in deflection is measured at right angles to the line of fire in a horizontal plane.

DODIC–Department of Defense identification code. A four- digit alphanumeric code used to identify a specific type of ammunition. *See* NALC.

DUAL THRUST ROCKET MOTOR–A solid propellant rocket motor used in medium-range guided missiles that has the booster propellant grains cast over the sustainer propellant grains. After the booster propellant is consumed, the sustainer propellant takes over to power the missile to the target.

ELEVATION–The movement of a weapon in a plane perpendicular to the deck.

ENFILADE FIRE–Gunfire on a ground target whose long axis is parallel to the line of fire.

ERROR OF THE MEAN POINT OF IMPACT–The distance of the MPI from the target or other reference point, measured parallel to the line of fire to determine range and at right angles to the line of fire to determine deflection.

FAIRING–Structural additions to improve streamlining.

FILTER–A device used to remove small particles from hydraulic fluid.

FIRING CUTOUT MECHANISM–A device that prevents a gun or missile launcher from firing into own ship's permanent structure.

FIXED AMMUNITION–Gun ammunition with the complete round (projectile, cartridge case, and primer) assembled in one piece.

GAS EJECTOR–A pneumatic device that blasts air through the gun bore after firing, to expel unburned gases.

GRAZE–A gunfire-support term meaning that the last round spotted detonated at the surface of Earth.

GRID SPOT CONVERTER–A graphic computer that converts spots from an observer ashore into terms usable by gun fire control.

GUN–A tube, closed at one end, from which a projectile is ejected by the rapidly expanding gases produced by a burning propellant.

HANG FIRE–An accidental delayed ignition of the primer, igniter, or propelling charge.

HARASSING FIRE–Sporadic gunfire intended to prevent enemy rest and recuperation.

HITTING SPACE–Measured in range, it is the distance a target can be moved away from the firing point and still be struck by a gun projectile that would have struck the target's highest point while located at the original location.

HOUSING (GUN)–The chief support of recoiling parts; houses the breech mechanism and barrel.

INDIRECT FIRE–Gunfire delivered against a target that is not itself used as a point of aim by the firing ship.

INERTIAL GUIDANCE–A missile guidance system that is designed to fly a predetermined path.

INITIAL VELOCITY (IV)–The speed of a projectile (in feet per second) at the muzzle of the gun.

INTERDICTION FIRE–Gunfire used to prevent or curtail the use of an area by the enemy.

INTERIOR BALLISTICS–Projectile motion and behavior while in the bore of the gun; most commonly concern those elements that effect initial velocity (IV).

LINE OF SIGHT (LOS)–A straight line joining the sight and the point of aim.

LOT NUMBER–An ammunition coding system that identifies a specific manufactured lot of that particular NALC/DODIC.

MAGAZINE–Compartments aboard ship designated for ammunition stowage.

MEAN POINT OF IMPACT (MPI)–The geometrical center of points of impact of all projectiles that are fired or released at the same aiming point at the same approximate time.

MIDCOURSE GUIDANCE–A phase of missile guidance used to either acquire the target or bring the missile near the target.

MINE–A thin-cased weapon filled with high explosives and designed to explode when struck or approached by a ship or submarine.

NALC–Navy ammunition logistics code. A four-digit alphanumeric code used to identify a specific type of ammunition. *See* DODIC.

NEUTRALIZATION FIRE–Rapid, fairly accurate gunfire delivered to hamper enemy movement and action.

OGIVE–The forward curved or conical part of a projectile.

OPPORTUNITY FIRE–Gunfire delivered without formal planning on newly discovered targets.

ORDNANCE–Weapons and all physical equipment pertaining to them.

PARALLAX–The angular difference that results from making observations or computations to one target from two different stations.

PASSIVE HOMING–A type of missile guidance that relies on radiated energy from the target, such as heat, to direct the missile.

PLENUM CHAMBER–A device that vents exhaust gases to the atmosphere from missile magazines in case of inadvertent firing of a stowed missile rocket motor.

POINT FIRE–Gunfire directed at a particular material target.

POINT OSCAR METHOD–A method of indirect naval gunfire support where the firing ship tracks a visible point ashore, making deflection corrections from this point to hit an unseen target.

PREPARATION FIRE–Prearranged neutralization fire delivered just prior to a landing or troop movement.

PRIMER–The first unit in a propellant train.

PROPELLANT TRAIN–Propellant igniting units designed to function in sequence.

RADAR BEACON–A lightweight electronic device used by a spotter in the field to provide the firing ship with an accurate reference point from which to spot gunfire support.

RAPID CONTINUOUS FIRE–The fastest firing method for guns.

RAPID FIRE–Continuous fire not delayed for the application of corrections.

RECOIL–The rearward thrust on gun produced when the gun fires; the movement of gun parts in response to this thrust.

RIFLING–The spiral grooves cut in the inner surface of a gun bore that impart the stabilizing spin to a projectile as it passes through the gun bore.

ROLLER PATH–Roller bearing surface on which a weapon or fire control element moves in train.

ROLLER PATH COMPENSATOR–A mechanical device incorporated into the elevation receiver-regulator of a gun that introduces small offsetting elevation error signals at train angles where the roller path plane differs from the reference plane.

ROTATING BAND–The soft copper band around the base of a gun projectile that engages, and is engraved by, the rifling in the gun bore, imparting spin to the projectile as it passes through the bore of the gun. The rotating band also serves as a seal, preventing propellant gases from escaping around the projectile as it is fired from the gun.

SAFETY LINK–A detachable metal link between the gun housing and slide that is designed to hold the housing in battery should the counterrecoil system fail or be deactivated. The safety link is disconnected prior to firing.

SALVO–One or more shots fired simultaneously at the same target by the same battery.

SCREENING FIRE–Gunfire using smoke projectiles to mask friendly troop movements.

SEMIACTIVE HOMING–A type of missile guidance that uses a radar receiver in the missile and the ship's fire control system as the transmitting source of target-illuminating energy. Reflected energy from the target is used by the missile to guide it to the target.

SIGHT ANGLE–The vertical component of the angle between the line of sight and the axis of the bore of a gun.

SLIDE–The structural support for all parts of a gun mount that move in elevation.

SLOW FIRE–Deliberate delayed fire to allow for spots to be applied.

SLOW SALVO FIRE–When the guns of an entire battery are loaded on command and fired together at a fairly slow rate.

SPOT–The correction to be applied to gun position in order to hit a target.

SPOT PYRAMIDING–The application of a new spot before the effect of a previous spot has had time to become apparent.

STABLE ELEMENT–A gyroscope device that maintains a reference plane.

STACK–A sonar unit for producing transmitted pulse and reproducing echo.

STAND–The foundation of gun mount or missile launcher. This incorporates the training circle, and is secured to ship structure.

STAR GAGE–An instrument for measuring wear in a gun bore.

STRAINER–A filtering device used to remove large particles from hydraulic fluid.

SUPPRESSION FIRE–Gunfire used to deny the enemy use of selected weapons for a period of time.

SUSTAINER–A missile propulsion unit that functions to keep the missile at flight speed and moving toward the target.

TARGET DATA–Processed information concerning a target's course, speed, bearing, range, identity, and type.

TERMINAL GUIDANCE–A phase of missile guidance that brings the missile in contact or close proximity to the target.

THERMOCLINE–A layer of seawater in which density changes rapidly with depth.

TORPEDO–A self-propelled weapon that carries a high- explosive weapon to an enemy ship or submarine.

TRAIN–The movement in the horizontal plane of a gun mount or launching equipment.

TRAIN ALIGNMENT–The alignment of weapon system elements so that they are "in effect" all parallel and all at exactly the same angle to a selected vertical plane.

TRAMMING–A procedure for verifying train and elevation dial accuracy.

TRANSDUCER–A device that translates sound waves into electrical signals, and vice versa.

TRANSMISSION CHECK–The process of verifying the accuracy with which a gun or missile launcher responds to orders from the fire control system.

TRUE WIND–Wind as it exists with respect to Earth; independent of any motion of the ship.

TRUNNIONS–Part of the gun slide. The center of rotation in elevation movement.

UPPER CARRIAGE–The part of the gun mount rotating structure that contains the trunnion bearings.

WDS–Weapon direction system. The equipment used to automatically assess target data and schedule and control the engagement of targets by the ship's weapon systems. Also referred to as weapon control system (WCS).

WEAPON CONTROL REFERENCE PLANE–The reference equipment to which all other equipments in a combat system are aligned– usually the roller path of a centrally located component.

WILD SHOT–A shot with an abnormally large dispersion in range, deflection, or both.

APPENDIX II

ORDNANCE SAFETY PRECAUTIONS

This appendix represents a sampling of ordnance safety precautions taken from NAVSEA OP 4, *Ammunition Afloat*. It is not intended to replace the original publication, but to give you an understanding of the types of ordnance safety regulations currently in effect.

Atmospheric Disturbances. Ammunition evolutions involving direct contact with ammunition components shall be curtailed during atmospheric disturbances, thunder storms which are within a 10-mile radius of the evolutions, or high winds.

Cleanliness in Magazines. All magazines and other spaces containing ammunition or explosives shall be kept scrupulously clean.

Emergency Drills. Emergency drills requiring the use of the general alarm system, ship's bell, or whistle shall not be conducted on board ship while moored to an ammunition activity pier unless specific approval for such drills has been granted by the commanding officer of the ammunition activity.

Firefighting. Adequate fire alarm systems and fire-fighting equipment shall be installed at appropriate locations and maintained in serviceable condition. Prior to conducting ammunition or explosives loading or offloading operations, either at a shore activity or underway, all firemains shall be inspected to ensure their efficient and proper operation. Fire hoses shall be laid out ready for use in the immediate area of operations such that at least single-hose coverage is provided for all points along the weapons-handling path.

Food and Drink. Food and drink are prohibited in magazines and magazine areas.

Magazine Temperature Log. A card shall be posted in the magazine in a conspicuous place near the thermometer for recording the daily maximum magazine temperatures. The magazine temperature data cards/forms shall be retained for a period of 1 year. Magazine temperature for each month shall be posted in the permanent log. Temperatures in excess of 100°F shall be recorded in a conspicuous manner (i.e., red ink).

Minimizing Handling Operations. Handling of live ammunition shall be kept to a minimum to reduce the chance of accidents and to prevent damage to containers, tanks, missile sections, and other thin-walled ammunition cartridge cases and similar material.

Night Operations. Ammunition and explosives shall not be loaded on or discharged from a ship, lighter, or barge at night except when required by the loading schedule or in an emergency.

Number of Personnel. The number of personnel engaged in ammunition and explosives-handling operations shall be limited to the minimum necessary for the safe and efficient performance of the work.

Personnel Procedures. Personnel involved in handling or transporting explosives shall be trained to perform their work expeditiously and safely. Shipboard personnel shall be trained under the direct supervision of experience commissioned officers or petty officers until they are competent to perform their work under less direct supervision. Personnel handling or transporting ammunition shall be qualified and certified under the provisions of OPNAVINST 8023.2 and other command directives.

Pilferage. Every effort shall be made to prevent ammunition or explosives from falling into unauthorized hands during loading, offloading, and stowage.

Privately Owned Ammunition and Arms. Stowage of privately owned ammunition and arms is permitted aboard ship if approved by the commanding officer and is subject to the security requirements of OPNAVINST 5530.13.

Projectiles. When a loaded and fuzed projectile, except rocket assisted projectiles (RAPs), is dropped 5 feet or more, it shall be set aside, tagged, and turned in to an ammunition activity at the first opportunity, or dumped in deep water at the discretion of the commanding officer. Any RAP dropped more than 24 inches should be considered defective and turned over to authorized ordnance disposal personnel for disposition.

Smoking. Smoking is prohibited in a magazine or magazine area, and personnel shall not be permitted to carry cigarette lighters or any open flame or spark- or flame-producing apparatus in these areas.

APPENDIX III

PUBLICATIONS AND INSTRUCTIONS

This appendix provides you with a ready reference and brief description of the commonly used publications and instructions pertaining to the ordnance world. System publications are not included in this appendix.

SECTION ONE–PUBLICATIONS

Ammunition Afloat, NAVSEA OP-4. Prescribes the minimum requirements and regulations for the issue, receiving, handling, stowage, surveillance, maintenance, and return of conventional ammunition and the preparation of associated reports by units afloat.

Ammunition Ashore, NAVSEA OP-5, volumes 1 and 2. A safety manual containing the instructions and regulations necessary for safe ammunition production, handling, storage, assembly and shipment, and other ordnance operations at Naval and Marine Corps shore establishments.

Clearing of Live Ammunition from Guns, NAVSEA SW300-BC-SAF-010. Provides operating personnel with exact procedures and precautions to be used when clearing live ammunition from guns.

Demolition Materials, NAVSEA SW060-AA-MMA-010. Describes demolition devices, materials, and equipment currently available for fleet use. It also sets forth applicable safety requirements and safety precautions, and prescribes procedures for the preparation and conduct of demolition operations both on land and underwater.

Identification of Ammunition, NAVSEA SW010-AF-ORD-010. Describes the system identifying ammunition, ammunition components, and ammunition containers by use of color codes, markings, and lettering.

Navy Gun Ammunition, NAVSEA SW030-AA-MMO-010. Provides descriptive information on Navy surface gun ammunition over .60 caliber and items closely associated with gun ammunition.

Pyrotechnic, Screening, Marking and Countermeasure Devices, NAVSEA SW050-AB-MMA-010, Volumes 1 and 2. Volume 1 contains descriptive information pertaining to serviceable pyrotechnics, dye markers, screening devices, chemiluminescent, and countermeasure devices. Volume 2 contains similar information on unserviceable and obsolete items of the same type.

United States Navy Ammunition Historical and Functional Data, NAVSEA SW010-AB-GTP-010. A general publication intended to increase the overall knowledge of persons in the ordnance field. Not intended for technical use.

United States Navy Ordnance Safety Precautions, NAVSEA OP-3347. A safety publication containing instructions and regulations for safe ammunition-handling and ordnance operations aboard ship and at shore stations.

SECTION TWO–INSTRUCTIONS

Conventional Ammunition Integrated Management System, SPCCINST 8010.12. Defines policy, provides procedures, and assigns responsibilities for the supply management of ammunition.

Department of the Navy Physical Security Instruction for Conventional Arms, Ammunition, and Explosives (AA&E), OPNAVINST 5530.13. Sets forth Department of the Navy policy and guidance for the protection of conventional AA&E against loss or theft.

Explosives Handling Personnel Qualification and Certification (QUAL/CERT) PROGRAM, COMNAVSURFLANTINST 8023.4/COMNAVSURFPACINST 8023.5. Sets up a standard Qual/Cert program within NAVSURFLANT and NAVSURFPAC according to the instructions in OPNAVINST 8023.2.

Procedures for Shipboard Explosives Safety Inspections, OPNAVINST 8023.23. Provides information concerning the Navy standards for conducting shipboard safety inspections and establishes procedures for the conduct of these inspections.

Ship/Submarine Explosives Safety Surveys and Checklists, NAVSAFECENINST 8020.1. Checklists used during the shipboard safety surveys required by OPNAVINST 8023.23.

Small Arms and Weapons Management Policy and Guidance Manual, OPNAVINST 8370.2. Provides policy and guidance relative to small arms and weapons management.

U.S. Navy Explosives Safety Policies, Requirements, and Procedures (Department of the Navy Explosives Safety Policy Manual), OPNAVINST 8023.2. Provides the principal naval explosives safety policies and procedures approved by the Office of the CNO.

Many of these instructions are the parent to LANT or PAC Fleet instructions that you will actually use during your daily routine. As an ordnance manager, you should keep a current library of all these publications on hand for ready reference.

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☆ U.S. GOVERNMENT PRINTING OFFICE:1992-631-080/40098

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